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BOSTON SOCIETY OF CIVIL ENGINEERS

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PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY AFTERNOON, JUNE 21, 1916,

at the Pemberton Inn, Hull, Mass.

The meeting will be called to order at the close of the shore dinner, which will be served in connection with the Joint Field Day and Excursion of the New England Water Works Association and this Society. It is expected that Rear Admiral Robert E. Peary will address the Society on "National Preparedness."

S. E. TINKHAM, *Secretary*.

PAPERS IN THIS NUMBER.

"The Yale Bowl," T. C. Atwood.

"Mosquito Extermination in Panama and New Jersey,"
H. I. Eaton.

"Reform and Regulation," A. C. Humphreys.

Discussion of "Power Estimates from Stream Flow and Rainfall Data."

Memoir of Deceased Member.

CURRENT DISCUSSIONS.

Paper.	Author.	Published.	Discussion Closes.
"Pan-American Use of Metric System."	F. Brooks.	Feb.	Aug. 10.
"Spillways of the Panama Canal."	E. C. Sherman.	April.	Aug. 10.

Paper.	Author.	Published.	Discussion Closes.
"Latest Method of Sewage Disposal."	E. Barton.	April.	Aug. 10.
"Service for the Society."	E. M. Blake.	April.	Aug. 10.
"Dorchester Tunnel."	A. A. Cohill.	May.	Aug. 10.
"Cambridge, Ohio, Water Works."	W. J. Sherman.	May.	Aug. 10.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

BOSTON, MASS., April 27, 1916. — A special meeting of the Boston Society of Civil Engineers was held this evening in the Society's Rooms, and was called to order at 8 o'clock by the President, Richard A. Hale. Thirteen members and visitors were present.

The subject for discussion as announced in the notice of the meeting was, "Practical Steps Remaining to be Taken in Completing the Abandonment of Ancient, Customary Units by the Substitution of the Metric System of Weights and Measures."

The discussion was opened by Past President Frederick Brooks, who was followed by Robert Spurr Weston, Alfred W. Parker, Edward P. Adams and others.

At 10.20 the meeting adjourned.

S. E. TINKHAM, *Secretary*.

BOSTON, MASS., May 17, 1916. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order at 8 o'clock by the President, Richard A. Hale. There were 60 members and visitors present.

By vote, the record of the April meeting was approved as printed in the May JOURNAL, and that of the special meet-

ing held on April 27 was, after reading by the Secretary, also approved.

The Secretary reported for the Board of Government that it had elected the following to membership in the grades named:

Members — Guy Herbert Chase, Henry Emery Holmes and Ernest Elwell Lothrop.

Juniors — Frank Rundlett Coburn, Thomas Ewing Hannah and Leo Joseph Nawn.

The Secretary also reported for the Board of Government that an invitation had been received for the Society to participate in the Preparedness Parade, to be held in Boston on May 27, 1916, and the recommendation of the Board that the Society take part in the parade and the President be authorized to appoint a committee to have charge of the matter. On motion of Mr. Fay, the recommendation was adopted by a unanimous vote.

The President has appointed the following as members of that committee: Charles R. Gow, chairman; Frank M. Gunby, Richard K. Hale, Christopher Harrison and Edmund M. Blake.

The Secretary announced the deaths of Mr. Charles W. Ross, a member of the Sanitary Section, which occurred on April 11, 1916, and Dr. Elmer L. Corthell, a member of this Society and president of the American Society of Civil Engineers, which occurred on May 16, 1916.

By vote, the President was authorized to appoint committees to prepare memorials.

The Secretary presented the memoir on our late associate, Erasmus Darwin Leavitt, an honorary member of the Society, prepared by a committee consisting of Charles T. Main and Will J. Sando. By vote, the memoir was accepted and ordered printed in the JOURNAL.

Mr. Thomas C. Atwood then read the paper of the evening, entitled, "The Construction of the Yale Bowl." The paper was illustrated by a large number of lantern slides. At the conclusion of the reading of the paper, Mr. Atwood very kindly answered numerous questions which were asked in relation to the construction of the Bowl.

Adjourned.

S. E. TINKHAM, *Secretary*.

BOSTON, MASS., April 5, 1916. — A meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening in the Society Library, Tremont Temple. There were 18 members who met informally at Marston's restaurant for dinner before the meeting.

The meeting was opened by Chairman Frederic Bonnet, Jr., at 7.25 P.M.

The minutes of the March annual meeting were read and approved.

A preliminary report of the Committee on "Methods of Design and Construction and Results of Operation of Inverted Siphons for Carrying Sewage Only and for Storm Water" was presented by the chairman, Wm. S. Johnson. Discussions of the subject were presented by Messrs. Dwight Porter, Otis F. Clapp, J. Leslie Woodfall, Harrison P. Eddy, Edgar S. Dorr, Lewis M. Hastings, Bertram Brewer, Frederic A. Caldwell, Henry A. Varney and Laurence B. Manley.

It was evident that the committee had gathered a large amount of data concerning inverted siphons, and the final report of the committee when presented should be a valuable addition to engineering literature.

There were 54 present at the meeting. The meeting adjourned at 10 o'clock.

FRANK A. MARSTON, *Clerk*.

BOSTON, MASS., May 3, 1916. — A meeting of the Sanitary Section, Boston Society of Civil Engineers, was held this evening in the Society Library, Tremont Temple.

The meeting was opened by Chairman Frederic Bonnet, Jr., at 7.25 o'clock. The minutes of the April meeting were read and approved.

The Clerk announced that, by vote of the Executive Committee, in accordance with authority of the Section (vote of March 1, 1916), the following have been appointed as a committee on Sewer Assessments:

Wm. S. Johnson, *Chairman*.

H. P. Eddy.

F. A. Barbour.

W. P. Morse.

E. Worthington.

E. S. Larned.

The speaker of the evening, Mr. Arthur R. Keller, professor of civil engineering in the Hawaiian College, gave a very interesting and entertaining talk on "Sanitary and Hydraulic Work in the Hawaiian Islands." Mr. Keller has had an exceptional opportunity to study sanitary conditions and works of this character, because of his membership in the Territorial Board of Health, of which he has been president. The talk was illustrated by about one hundred and twenty-five lantern slides, some of which were colored. Not only did he describe sanitary and hydraulic work, but also some details of the sugar industry and other features of popular interest in connection with the Hawaiian Islands.

It was voted to extend to Mr. Keller a rising vote of thanks for his courtesy in presenting the paper of the evening.

There were 37 present, and the meeting adjourned at 9.40 o'clock.

FRANK A. MARSTON, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[June 8, 1916.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission, and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as references does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

FORD, ARTHUR LEON, Danvers, Mass. (Age 29, b. Savoy, Mass.) Graduate of Worcester Polytechnic Inst., 1911, civil engineering course. From February to August, 1910, draftsman with Ludlow Mfg. Associates, Ludlow; from July to November, 1911, rodman and transitman with Clapp & Abercrombie Co., Greenfield; from November, 1911, to September, 1912, junior partner and transitman with A. F. Brown, Greenfield; from September, 1912, to September, 1913, transitman and chief-of-party with Clapp & Abercrombie Co.; from September to December, 1913, transitman and inspector with Mass. Highway Comm.; from June, 1914, to date, transitman and resident engineer with Mass. Highway Comm. Refers to J. K. Barker, A. P. Rice, F. D. Sabin, G. P. Soutar and A. E. Tarbell.

KLINK, NASSIME SOLOMON, Boston, Mass. (Age 32, b. Mt. Lebanon Syria.) Student for two years at College National, Baabdat, Syria, 1895 to 1897; took correspondence course in civil engineering; graduate of Mass. Inst. of Technology, 1915, civil engineering course. In 1906, architectural draftsman with Joseph Robichau, Lawrence, Mass.; from 1907 to 1910, rodman and instrumentman with John Franklin, Lawrence; during college course and since graduation has practiced engineering and architecture in Boston and Lawrence; is now instrumentman with Fore River Shipbuilding Corp'n. Refers to C. F. Allen, C. B. Breed, Dwight Porter and C. M. Spofford.

SNOW, BENJAMIN HARRISON, Everett, Mass. (Age 23, b. Everett, Mass.) Received technical education at Evening Polytechnic School of Boston Y. M. C. A., completing surveying course in 1913 and four-year structural engineering course in 1916. From August, 1913, to April, 1914, and from August to October, 1914, transitman and inspector at new fish pier, South Boston; from April to August, 1914, transitman with Whitman & Howard, Boston; from October, 1914, to May, 1915, draftsman on ornamental iron and light structural steel with Babcock-Davis Corp'n, Cambridge; is now civil engineer with Industrial Service & Equipment Co., Boston. Refers to B. S. Brown, C. S. Ell, Channing Howard and T. E. Penard.

LIST OF MEMBERS.

ADDITIONS.

APPLETON, THOMAS A.....	237 Essex St., Salem, Mass.
CRAIGUE, JOSEPH S.....	Town Hall, Walpole, Mass.
ELLSWORTH, SAMUEL M.....	117 Adams St., Braintree, Mass.
FARRELL, FRANCIS B.....	76 Francis St., Roxbury, Mass.
LOTHROP, ERNEST E.....	21 Allston Pl., Fitchburg, Mass.
TURNER, JOHN M.....	384 Washington St., Brookline, Mass.

PROCEEDINGS.

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CHANGES OF ADDRESS.

ALLEN, JOHN E.....	316 Huntington Ave., Boston, Mass.
ARMSTRONG, KENNETH P.....	1512 Kearney St., N. E., Washington, D. C.
BLAKE, EDMUND M.....	6 Beacon St., Boston, Mass.
CLAPP, FREDERICK O.....	11 Bridgham St., Providence, R. I.
CLAPP, OTIS F.....	11 Bridgham St., Providence, R. I.
DOTTEN, WM. J.....	14 Reservoir St., Winchester, Mass.
DUFFY, J. HENRY.....	25 Maple St., Lexington, Mass.
GALLAGHER, JOHN P.....	16 Hawthorne St., Watertown, Mass.
GLADDING, RAYMOND D.....	662 Western St., West Lynn, Mass.
HARTY, JOHN J., JR.....	78 Devonshire St., Boston, Mass.
HUNTER, ROBERT C.....	51 Harbor View Ave., Winthrop, Mass.
KEITH, HERBERT C.....	154 Nassau St., New York, N. Y.
LOVIS, ANDREW M.....	Rm. 212, State House, Boston, Mass.
MEAD, ROYAL L.....	30 Hemenway St., Boston, Mass.
NEWSOM, REEVES J.....	84 Eastern Ave., East Lynn, Mass.
SAVAGE, J. DANA.....	258 Park Pl., Woonsocket, R. I.
SMITH, EDWARD R.....	River John, Pictou Co., Nova Scotia
STONE, GEORGE C.....	Hurt, Va.
STRADLING, DAVID W.....	131 Ingalls Bldg., Cincinnati, Ohio
TREADWELL, EDWARD D.....	101 Linden Ave., Malden, Mass.
VAN RENSSLAER, ALLEN.....	718 Petaluma Ave., San Rafael, Calif.
WOLFE, CHRISTIAN F.....	525 58th St., Brooklyn, N. Y.

DEATH.

CORTHELL, ELMER L.....	May 16, 1916
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EMPLOYMENT BUREAU.

THE Board of Government maintains an employment bureau for the Society, to be a medium for securing positions for its members and applicants for membership, and also for furnishing employees to members and others desiring men capable of filling responsible positions.

At the Society rooms two lists are kept on file, one of *positions available* and the other of *men available*, giving in each case detailed information in relation thereto.

MEN AVAILABLE.

359. Age 48. Received technical education at Mass. Inst. of Technology. Has had wide experience in all branches of municipal engineering, including sewerage, water-supply protection, etc.; experience also includes

highway engineering and grade-crossing elimination. Will accept position at moderate salary.

360. Age 32. High school graduate; student for one year at Franklin Union. Experience includes three years with engineering firm in Massachusetts; one year on irrigation work in Colorado; eight months as assistant superintendent on Shoshone Dam, Cody, Wyo.; five years as assistant engineer on railroad construction in Panama for United Fruit Co.; six months as chief engineer on construction of small railroad in Nicaragua; and six months as instrumentman and inspector on New York Subway. Desires position as superintendent on concrete construction or as inspector of masonry. Salary desired, \$25 per week, with prospect of advancement.

361. Age 52. Has had twenty-five years' experience, including water and sewer construction, permanent road construction of all kinds, underground construction for telephone and electric lights, and heavy reinforced concrete construction for bridge work, culverts and buildings. Salary desired, \$100 per month.

362. Age 30. Passed examination for supervisor, Water State of Holland, 1908. Experience includes five and one-half years as supervisor and draftsman on building and bridge construction in Holland; one year in Belgium as inspector, testing materials for Technic Bureau of Colonies in Holland; and more than three years as rodman, draftsman and asst. engineer in Canadian and western cities. Salary desired, \$75 per month.

363. Age 23. Graduate of Mechanic Arts High School; student at Tufts College Engineering School, class of 1916. Has had ten months' experience on building and dam construction. Desires position as rodman, transitman or timekeeper. Salary desired, \$60 per month.

364. Age 25. Fourth-year student at Mass. Inst. of Technology, civil engineering course. Experience consists of two years' and four summers' work as timekeeper and general assistant in office of firm of builders in Brooklyn, N. Y. Desires position with contractor. Salary desired, \$60 per month.

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Analyses of Coal Samples from Various Parts of United States. Marius R. Campbell and Frank R. Clark.

Atlantic Gold District and North Laramie Mountains, Fremont, Converse, and Albany Counties, Wyoming. Arthur C. Spencer.

Forest Conservation for States in Southern Pine Region.
J. Girvin Peters.

Results of Observations made at United States Coast and
Geodetic Survey Magnetic Observatory near Tucson, Arizona,
1913 and 1914. Daniel L. Hazard.

State Reports.

Massachusetts. Annual Report of Directors of Port of
Boston for 1915.

Massachusetts. Annual Report of Gas and Electric Light
Commissioners for 1914-15.

Massachusetts. Report of State Board of Health relative
to Disposal of Sewage in South Metropolitan Sewerage District
and to Extension of Limits of District, 1914.

Massachusetts. Report of State Department of Health on
Protection of Public Health in Valley of Neponset River, 1916.

Michigan. Annual Report of State Board of Health for
1913-14.

Wisconsin. Physical Geography of Wisconsin. Lawrence
Martin.

Municipal Reports.

Concord, N. H. Annual Report of Water Commissioners
for 1915.

Fitchburg, Mass. Annual Report of Water Commissioners
for 1915.

Fitchburg, Mass. Semi-Annual Reports of Sewage Dis-
posal Commission for 1915.

Holyoke, Mass. Annual Report of Water Commissioners
for 1915.

Medford, Mass. Annual Report of Water and Sewer Com-
missioners for 1915.

New Bedford, Mass. Annual Report of Engineering De-
partment for 1915.

Taunton, Mass. Annual Report of Water Board for 1915.

Ware, Mass. Annual Report of Water Commissioners for
1915.

Wilmington, Del. Report on New Castle County Highways. Arthur H. Blanchard, Henry G. Shirley and George W. Tillson.

Worcester, Mass. Annual Report of Superintendent of Sewers for 1915.

Worcester, Mass. Annual Report of Water Commissioner for 1915.

Miscellaneous.

International Engineering Congress, 1915: Transactions: Naval Architecture and Marine Engineering.

New International Encyclopædia, Vols. 19 and 20.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.—METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.*

Sudbury Hydro-Electric Power Plant. — The electrical machinery is being installed at the Sudbury Dam in Southborough.

Sewerage Works. — Work is in progress on Sects. 103 and 104, the Wellesley extension sewer; and on Sect. 1A, the outfall sewer at Deer Island. Sect. 19, the Malden River Siphon, is completed.

Work contemplated consists of Sects. 98 and 99, Wellesley Extension Sewer, which are under contract; and the extension of Sect. 1, Deer Island outfall.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Alewife Brook Parkway. — Surfacing and finishing Alewife Brook Parkway, from Massachusetts Ave. to Powder House Boulevard. Kelley & Sullivan, contractors.

Charles River Reservation. — Reinforced concrete bridge over the Charles River at North Beacon St., Boston and Watertown. A. G. Tomasello, contractor. Reinforced concrete bridge over the Charles River at Commonwealth Ave., Newton and Weston. T. Stuart & Son Company, contractor. Excavating channel of Charles River from Elm St. to Bleachery Dam, Waltham. John R. Burke, contractor.

Furnace Brook Parkway. — Parkway extension from Quincy Shore Reservation to Hancock St. John Cashman & Sons Company, contractor.

Mystic Valley Parkway. — Channel of Aberjona River from Boston & Maine Railroad Bridge to Waterfield St. Coleman Brothers, contractors.

Old Colony Parkway. — Plans are being prepared for bridge over the Neponset River, Boston and Quincy, to replace old wooden bridge.

General. — The work of repairing road surfaces in all divisions is in progress.

DIRECTORS OF THE PORT OF BOSTON. — *South Boston Dry Dock.* — Under the contract with the Holbrook, Cabot & Rollins Corp'n, for the construction of the Dry Dock, further progress has been made in the assembly of materials and plant and the construction of railroad tracks. The cofferdam is nearing completion and a boiler plant and pump for unwatering the dry-dock site are being installed. The total amount of dredging to date at the turning basin near the main ship channel is about 350 000 cu. yds.

Extension of Northern Avenue. — The W. H. Ellis & Son Co., the contractor for the construction of about 1 000 ft. of timber bulkhead for the extension of Northern Ave., began the driving of piles for this work on May 20, 1916.

Sewer in Fargo Street. — The contract with J. H. Ferguson for the construction of a sewer in Fargo St. between C and D Sts., to connect with the city sewer in C St., has been completed.

Reclamation of Flats at East Boston. — Under the contract with the Bay State Dredging & Contracting Co., for the construction of timber and bulkhead extending easterly from Jeffries

Point, about 1 000 ft. of bulkhead has been completed and about 75 000 cu. yds. of dredging and filling has been done.

Rehandling Plant. — Work has been begun under the contract with the Atlantic, Gulf & Pacific Co. for the rehandling of about 1 000 000 cu. yds. of material for the reclamation of about 35 acres of state flats at East Boston, east of Jeffries Point. The dredge used is the *Pittsburg*, one of the largest of its kind, a hydraulic suction dredge having suction and discharge pipes each 27 ins. in diameter. The portion of the work started upon is the construction of the earth dikes along the easterly side of the area to be reclaimed.

Mystic River Dredging. — The Maryland Dredging Co., having a contract for removing about 500 000 cu. yds. of material from Mystic River above the Chelsea Bridge, has dredged to date about 120 000 cu. yds. The dipper dredge *Governor Warfield* is employed on this work. The dredged material has been deposited largely at East Boston within the area designated as the receiving basin, east of the anchorage basin, for rehandling under another contract for the reclamation of state flats.

Neponset River Dredging. — Under contract with the Gerish Dredging Co. for removing about 35 000 cu. yds. of material from Neponset River at Milton, near Milton Lower Mills, work was started on April 17, 1916. The hydraulic dredge *Middlesex* is employed on this work, and is pumping this material upon a marsh area north of the area being dredged. The depth of water to be secured is 6 ft. at mean low water.

Wollaston Yacht Club. — The Morris & Cumings Dredging Co. has continued dredging at Wollaston. The depth to be secured is 8 ft. at mean low water for a width of 70 ft.

Boston Transit Commission. — *Dorchester Tunnel.* — Descriptions of Sections D, E, G and H were printed in the JOURNAL in October and December, 1915.

The work on the finish of South Station Under is nearing completion. It consists of setting doors, hand-rails, fences, etc., installing escalators, and rubbing down and polishing the concrete coverings over the stairways and escalators.

In Section E, the easterly tunnel has encountered the ad-

vance pilot drift which extends about 70 ft. east of the completed work in Summer St., and the shield is within a few feet of its final position, where the decks and inside framing will be removed and the shell left in the tunnel lining. The shield of the westerly or southbound tunnel is within 300 ft. of the end of the completed work in Summer St.

Section F was described in the May JOURNAL. Work is now in progress underpinning the buildings adjacent to the work and putting in the sidewalls of the tunnel station.

On Section G the construction of the tunnel structure in open cut between West Fourth and B Sts., in Dorchester Ave., is in progress.

Section J was also described in the May JOURNAL. Work has been started near Dexter St. and in Andrew Sq., and the excavation near Dexter St. is nearly to grade.

City of Boston. — PUBLIC WORKS DEPARTMENT, HIGHWAY DIVISION, PAVING SERVICE. — Work is in progress on the following streets:

Gladstone St.,	from Walley St. to Upland Ave.	Artificial stone walks.
Washington St.,	from Tip Top St. to the Newton line.	Artificial stone walks.
Glendower Rd.,	from Kittredge St. to Poplar St.	Asphalt pavement.
Kittredge St.,	from Cornell St. to Beech St.	Asphalt pavement.
Poplar St.,	from Sycamore St. to Brown Ave.	Artificial stone walks.
Poplar St.,	from Washington St. to Sycamore St.	Artificial stone walks.
Wachusett St.,	from Weld Hill St. to Barlow St.	Excavating and grading.
Montebello Rd.,	from Forest Hills St. to Walnut Ave.	Bitulithic pavement.
Jones Ave.,	from Mascot St. to Ballou Ave.	Asphalt pavement.
Rosewood St.,	from Oakland St. to Randolph Rd.	Asphalt pavement.
Sturtevant St.,	from Park St. to Gibson St.	Hassam block pavement.
Fernboro St.,	from Lawrence Ave. to Intervale St.	Asphalt pavement.
Public Alley No. 903,	from Haviland St. to Public Alley No. 904.	Hassam block pavement.
Public Alley No. 904,	from Bickerstaff St. to Public Alley No. 903.	Hassam block pavement.
Saratoga St.,	from Butler Ave. to Washburn Ave.	Artificial stone walks.

Boston Elevated Railway Company. — BUREAU OF ELEVATED AND SUBWAY CONSTRUCTION. —

Dudley St. Station. — In compliance with orders issued by the Public Service Commission, the pavilion on the East elevated loop, containing waiting-room, toilets, news booth, boot-black and barber shop, has been removed. The double stopping of cars will be discontinued, a single stop being substituted, unloading and

loading to occur simultaneously. An illuminated destination sign, similar to the one so successfully operated at the Park St. subway station, will be at once installed. At the lower level, an elevated column has been removed to permit the installation of a turnout from the outbound Warren St. surface track to the west-bound track in the surface prepayment area. These changes, together with the inauguration of a prepayment surface area at Egleston Sq., will, it is felt, relieve the congested traffic conditions at Dudley St. for many years to come.

Everett Extension. — Work by the Hugh Nawn Contracting Co. is progressing on the contract for the foundations for the Mystic River Bridge and Viaduct and the Malden Bridge changes. The contract for the superstructure, including the 95-ft. span, double-track, deck-plate girder, Strauss trunnion bascule bridge, and the 102-ft. span, pony truss, highway Strauss trunnion bascule bridge, is about to be let. This contract embraces the entire electrical and mechanical equipment, together with the erection and complete installation.

The Fore River Shipbuilding Co., Quincy, Mass., has the following work in progress:

Torpedo-boat destroyers *Sampson* and *Rowan*, U. S. Government.

Cargo vessel *Cubadist*, Cuba Distilling Co.

Molasses steamer *Sucrosa*, Cuba Distilling Co.

Molasses steamer *Mieler*, Cuba Distilling Co.

Two freight steamers, Texas Co.

Tank steamer, Argentine Government.

Freight steamer *K. I. Luckenbach*, Luckenbach Co., Inc.

Freight steamer *F. J. Luckenbach*, Luckenbach Co., Inc.

Freight steamer, Luckenbach Co., Inc.

Tank steamers, two, Petroleum Transport Co.

Eleven submarines for U. S. Government.

One submarine for the Spanish Government.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

THE YALE BOWL.

BY THOMAS C. ATWOOD.*

(Presented May 17, 1916.)

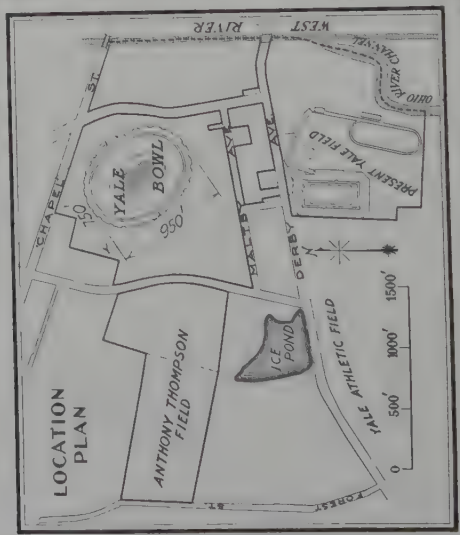
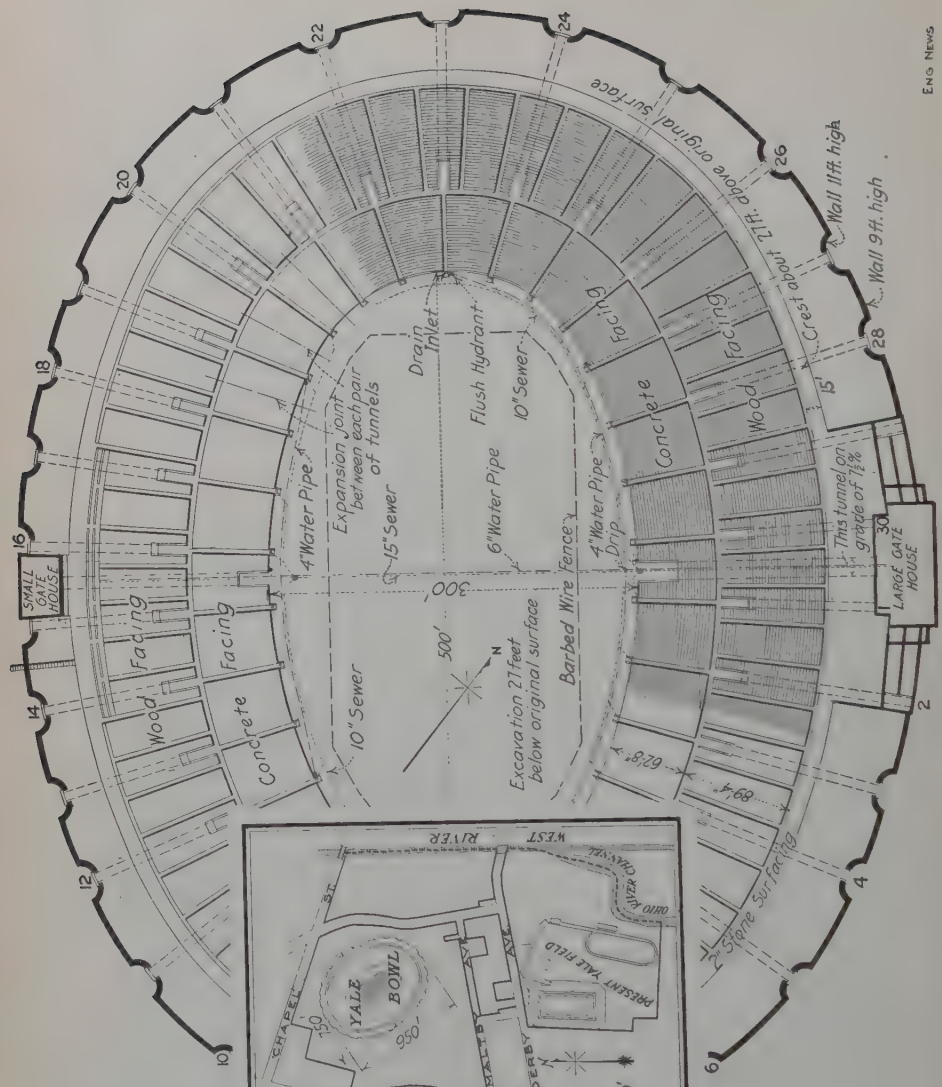
THE greatest of amphitheaters for the witnessing of outdoor sports has been erected at New Haven, Conn., for the use of Yale University.

It is designed especially for football contests, but can be used for outdoor pageants and spectacles and for any games which can be played upon the 300 ft. by 500 ft. oval-shaped playing field, but it is not suited to baseball or track games. The principal reasons for this are that, for the large seating capacity required, a field of the right size and shape for baseball would necessitate placing spectators too far away to properly see football, while the design of the structure is such that to accommodate the 220-yd. straightaway for the track games, a tunnel would be necessary, which would give poorer running conditions than a track in the open and which would cost as much to build as an ideal track with suitable grandstand on a nearby location.

The structure has been named "The Yale Bowl" on account of its resemblance to a huge bowl, rather than adopting the name of a similar ancient structure such as stadium or

NOTE. Discussion of this paper is invited, to be received by Edward C. Sherman, Editor, 6 Beacon Street, Boston, by August 10, 1916, for publication in a subsequent number of the JOURNAL.

* Consulting Engineer, New Haven, Conn.



colosseum. The Bowl follows closely the design of the stadium at Pompeii.

Work was started June 23, 1913, President Arthur T. Hadley turning the first sod. The structure was sufficiently complete to allow holding the first game within it on November 21, 1914.

LOCATION.

The Bowl is located on the western side of New Haven, about $1\frac{1}{2}$ miles from the center of the city and just north of the old Yale Field, on a level piece of ground lying between Chapel Street and Derby Avenue. It is on the west side of West River, and close to the high bank which the river has formed by cutting into the level plain of sand and gravel on which New Haven is largely built. (Fig. 1.)*

The location is an ideal one for this type of structure, the gravel and sand being coarse as a rule, but containing no cobblestones over 4 ins. in diameter. Much of the sand is excellent for concrete in its natural condition, while most of it can be made so by screening out the gravel, although some is too fine. The upper 10 ft., approximately, contains nearly all of the gravel. Below this depth is found sand varying in fineness, but generally free from particles over $\frac{1}{4}$ in. in size. This lower sand is, as a rule, very clean, while the sand in the upper 10 or 12 ft. is quite strongly colored by iron so as to give a pinkish tinge to the concrete made of it.

This location has the advantage of being about midway between two lines of street cars, while the direct road to the center of the city is free from cars at this point and can be used entirely by pedestrians when the big games are played. This operates to reduce very largely the danger of accident. A wide avenue was made on the easterly side of the Bowl, between it and the river bank, giving a dignified approach on this side. The northerly side is bounded by Chapel Street, and the south and west sides by land owned by the committee, which will be developed for athletic purposes.

* The Society is indebted to *Engineering News* for the cuts used to illustrate this paper.

DESIGN.

The Bowl differs from most modern amphitheaters in being essentially an earthwork structure. It is built in a level plain by excavating the center of the field and using the excavated material to make an embankment around the outside, this embankment forming a complete oval about the playing field. The seat slabs are placed directly upon the earth, making it a structure which cannot fall down.

The surface of the playing field is about 27 ft. below the original surface of the ground, while the top of the embankment is about 27 ft. above the original surface of the ground, the promenade around the top being 54 ft. above the playing field.

A wall 4 ft. high surrounds the field, thus giving 50 ft. rise in the bank of 60 rows of seats, or an average rise of 10 ins. per row. The actual rise varies increasingly from 8 ins. at the bottom to 12 ins. at the top, thus enabling spectators on all parts of the slope to see the field with equal facility.

Access to the Bowl for spectators is provided by 30 tunnels, each 7 ft. wide by 8 ft. high. These extend from the ground level outside to about midway of the seat bank, and aisles lead up and down the slope from the inner ends of the tunnels.

Access to the playing field from the outside is given by two tunnels, one 15 ft. wide by 10 ft. high and suited for entrance of vehicles, steam roller, etc., and the other 10 ft. wide by 8 ft. high and suited only for pedestrians, as it contains stairs, being the only tunnel so constructed. At the outer ends of these two tunnels, which are on the short axis of the ellipse, will be built two ornamental buildings called Gate Houses, in one of which the home team will be housed, while the visiting team will find quarters in the other. Access may also be had to the playing field by a flight of steps at the foot of each aisle.

After the games a considerable proportion of the spectators usually go down on to the playing field, and the two large tunnels just mentioned provide means of easy exit for these crowds as well as for the entrance and exit of processions and pageants.

The outside dimensions of the main structure are 933 ft.

by 744 ft., and the structure together with its approaches covers an area of 25 acres. The playing field is an approximate ellipse made up of circular arcs, the long axis being 500 ft. and the short axis 300 ft.

The field is so laid out that the main axis, which is also the long way of the football field, lies about northwest and southeast, so that the sun in the autumn afternoons will be at right angles to the long axis and will not shine in the eyes of the players looking toward either goal.

The principal quantities involved are as follows:

Excavation.....	300 000 cu. yds.
Embankment.....	175 000 cu. yds.
Concrete.....	25 000 cu. yds.
Concrete facing.....	110 000 sq. ft. done
Concrete facing.....	150 000 sq. ft. yet to be done
Steel reinforcement.....	500 tons
Granolithic pavement.....	36 000 sq. ft.
Drains, 6-in. to 24-in.	6 400 lin. ft.
Water pipe, 4-in. to 6-in.	4 700 lin. ft.
Waterproofing.....	48 000 sq. ft.
Pitch mopping.....	109 000 sq. ft.
Wood seat benches.....	20 miles
Area macadam walks.....	19 000 sq. yds.
Turfing.....	4 acres
Area graded.....	40 acres
Time of construction.....	17 months

EXCAVATION.

As stated previously, this stadium is essentially an earth-work structure, and consequently the excavation formed the biggest item. The loam which covered the site was first taken off and placed in separate piles of black loam and yellow loam. The depth of the black loam averaged about 10 ins. and of the yellow loam about 12 ins. Both were of a sandy quality, particularly the yellow loam, some of the latter being but little better than the sandy gravel beneath it.

The gravel was placed in the embankment at first partly by drag and wheel scrapers, but the main dependence for the excavation was placed upon two large drag-line excavators

operated from 85-ft. towers which moved on elliptical tracks built closely around the outside of the Bowl. These towers operated buckets weighing about 4 500 lbs. and having a capacity of about 2 cu. yds. The buckets were hauled in toward the tower by a single cable attached to a drum of the engine and run out by gravity on the main cable, which was pulled up taut by block and fall attached to the head of the tower, and held taut until the bucket had run out as far as desired and then slackened. The other end of the main cable was attached to a post which was moved from time to time so that the bucket might dig from the exact spot desired. Theoretically, a post could have been located at the center of any section of the track which was approximately a circular arc, and all of the material within the sector could have been removed by the bucket, but several practical considerations prevented this from being carried out in the main part of the excavation, although towards the end, when the banks were trimmed by dragging special buckets up the interior slope, this came very near to being the actual layout.

The maximum output of one of the excavators was about 1 500 cu. yds. running twenty-two hours, while the largest month's work for the two was about 45 000 cu. yds. Considerable experimenting was necessary before the exact design of bucket was found which would load itself in the bottom of the hole, and would travel up the slope without digging into the bank which had already been built. The proper shape was finally found, and the buckets worked very well with only an occasional accidental digging below grade, which usually took place during the night, when the light and supervision were not particularly good. Quite a little difficulty was experienced in digging through the 10 ft. of sandy gravel, which was fairly compact, although the buckets were heavy and equipped with strong teeth. After this was past, however, the digging was very good and the machines worked easily. Most of the excavation outside of the Bowl as well as a portion of that inside was made by two Thew rotary steam shovels with $\frac{5}{8}$ -cu. yd. buckets loading dump wagons.

EMBANKMENT.

The specifications called for the embankment above the tops of the tunnels to be rolled in 6-in. layers, and the method of operation was for the drag buckets to make three piles of material between each pair of tunnels, the piles being tent-shaped and usually about 3 ft. high, 8 ft. wide and as long as the bank width. These piles were figured to contain just enough material to make the 6-in. layer, being the most practical way in which to regulate this depth.

As the towers moved along, they were followed up by teams with leveling boards, which leveled off the piles to a fairly uniform surface, and this was thoroughly wet down by water from lines of hose and rolled eight times, each point being gone over four times by a grooved roller and four times by a smooth roller alternately. The rollers weighed about 800 lbs. per lin. ft. and as a rule required four horses, although occasionally a very heavy team would be found which could operate one for a few days without assistance. One larger roller, which required six horses, was used for a time. Large quantities of water were used. The contract called for 150 gals. per minute, to be run on to the bank night and day.

Below the tops of the tunnels, where rolling was not practicable, the material was watered very heavily, and after the fill had got above the tops of the tunnels, special efforts were made to make sure that the water had penetrated to every portion of the embankment by damming off a section at a time and running all of the water into this section, and punching holes in the bank about 8 ft. on centers by means of drills or water jets. In this way the whole embankment received a uniform treatment, which could not have been assured otherwise, for the sand was so porous that the water from a 2-in. hose would disappear into the bank within 5 or 6 ft. from the end of the hose, and with operation by the ordinary Italian water boy, it was impossible to tell whether every portion of the embankment had been thoroughly soaked or not.

When the embankment had been carried nearly to its full height, the excess material on the interior slope was dragged up

to the top of the bank by heavy timber frames operated by the drag scraper towers in the same manner as a bucket, these frames being about 10 ft. square and having heavy iron plates projecting below the front edge, acting much like a leveling board. They could be made to trim just where it was desired by tightening up the main cable so that they could not go below grade at any point, and they did very good work in shaping up the bank. The final trimming was by hand.

The outer slope of the embankment was trimmed partly by leveling boards operated by power and partly by hand, and was then covered with about 10 ins. of loam, into which strips of turf about 8 ft. on centers were embedded, running parallel to the top of the bank, with the idea that they would help to distribute rain water and prevent it from getting together in sufficient volume to do much damage before it struck another line of turf and was spread out again.

The outer slope of the embankment is sloped approximately 1 on 2, except around the portals, where it is about 1 on $1\frac{1}{2}$. These steep places were turfed entirely, but the remainder of the slope was seeded with a mixture of $11\frac{1}{2}$ lbs. of red top, 5 lbs. of Kentucky blue grass and 20 lbs. of white clover. This grew rapidly and seemed to be very good mixture for the purpose, the clover springing up quickly and protecting the grass while it was starting. In this region clover generally dies out after two or three years, while the red top is the native grass and will get a good start by that time.

During the placing of the loam and turf a torrential rain-storm occurred, in which the theory of the strips of turf was thoroughly tested and found to be correct. Small gullies formed between the strips of turf, being at most an inch deep at the upper end and 3 ins. deep at the lower end and close together, almost as if a very coarse rake had been dragged down the slope from one strip to another. In no instance did the water dig underneath the turf, and the gullies at the foot of the bank were very little larger than those up near the top. The total amount of dirt washed away was small, and the only repair necessary was going over with a rake to smooth the slope up once more.

RETAINING WALLS.

The outer slope is held at the bottom by a retaining wall 9 ft. high in the clear, and the inner slope is held at the bottom by a wall 4 ft. high in the clear. These are both heavy gravity type walls and are built in short lengths separated by pilasters, thus providing an ample number of contraction joints. The maximum length of wall without joint is about 23 ft.

The 9-ft. wall on the outside is made extra wide at the top so as to contain a gutter which takes the drainage from the slope above and carries it to drain pipes discharging down through a pipe built into the wall to the drain around the outside of the Bowl. A cross section of this wall is shown. The wall has stood well except in two places, where slight cracks have developed, due apparently to unequal settlement in the foundation. The main outer wall is connected to each of the tunnel entrances by two curved approach walls, approximately of similar design to the main wall. (Fig. 2.)

The interior wall also has a gutter around its top to take the flow from the inner slope, but this gutter instead of being open, as in the previous case, is covered with a cast-iron grating, as it forms part of the foot space under the seats.

The forms for both these walls were removed as soon as practicable, and the exposed surfaces rubbed up with wooden floats so as to remove board marks and leave a rough finish. This finish is on the whole quite satisfactory. The pilasters and coping of the exterior wall were finished with a smooth, hard-troweled surface with considerable neat cement added, and a good deal of crazing occurred, and in a few cases scaling started. An attempt was made to stop this by applying a waterproofing concrete paint, but it is too soon to tell whether this will be successful or not. The paint used was the "Transparent Driwal" of the Billings-Chapin Company, with a slight amount of the "Bluestone Driwal" added to cover the craze cracks and give a uniform color. The faces of the tunnel portals were covered with spatter-dash finish which looks very well, and has stood so far in good shape.

The two gate houses mentioned above set into the embank-

ment in such a way as to require retaining walls behind them of the full height of the bank from the outside ground level to the top. One of these is at the outer end of the Players' Tunnel, where the Smaller Gate House is to be erected, and the other at the end of the Main Tunnel, where the Main Gate House is to be erected. The former is of the gravity type, 34 ft. high, while the latter is of reinforced concrete cantilever type, without counterforts, being one of the highest walls of this type ever built, the maximum section being $45\frac{1}{2}$ ft. high from the bottom of the 3.5-ft. foundation to the top of the earth fill. It was realized that the counterfort type was more economical, but it was not used, as buttresses could not be placed on the front side without interfering with the building, and counterforts placed on the back side would have interfered with the rolling of the embankment. (Fig. 2.)

The wall was built by placing the foundation first as a separate operation and then carrying the vertical part of the wall up in monolithic sections of convenient length, the maximum length being about 47 ft. The maximum height placed in one day was 42 ft., and as this was placed mostly in cold weather, some trouble was had with the forms at first, due to insufficient bracing, but this was soon remedied, and the remainder of the wall was placed without accident.

The reinforcement was very heavy, and some unusual precautions were taken in connection with this. At the deepest section the main reinforcement consisted of $1\frac{1}{4}$ -in. square bars placed 3 ins. on centers, which left very little concrete between them. A splice was made in these bars just above the foundation by a five-foot lap, and it was feared it would have a tendency to split off the face of the concrete, due to internal strains being greater than the concrete could stand, so it was decided to place clamps upon the bars, which would have the double effect of preventing them from splitting out the surface of the concrete, and would also tie the bars together so that a large part of the stress would be carried from one bar into the other without going through the concrete at all. Some experiments were made to determine what could be done with these clamps, and results were as follows:

In the first test, a U-bolt of $\frac{3}{4}$ -in. steel was used, with heavy cast-iron cross head. The reinforcing bars used were the $1\frac{1}{4}$ -in. Havemeyer bars, and the clamp was put over two of these bars and tightened up moderately. The first slip was at 4 000 lbs., and amounted to $\frac{1}{4}$ in. before holding again. The bars were then taken out and put into a vise and the clamp tightened up hard with a 24-in. wrench. This time the first slip was at 5 100 lbs. and the test was continued until it held 19 800 lbs., by which time it had slipped $1\frac{1}{4}$ ins., most of this, however, being after 15 000 lbs.

The next test was on a $\frac{5}{8}$ -in. U-bolt with a plain steel strap cross head, the strap being $\frac{1}{2}$ in. thick and $1\frac{1}{2}$ ins. wide. This was tightened up with the 24-in. wrench and the first slip was at 2 700 lbs.

The next test was on the same, the first slip being at 3 200 lbs.

For the next test both clamps were put on and tightened up hard, the first slip occurring at 10 000 lbs.

In the next test the two clamps were used again, and put 16 ins. apart, a $\frac{1}{2}$ -in. bar being placed between the reinforcing bars half way between the clamps, with the idea that by bending the reinforcing bars around this small bar a greater resistance to slipping might be obtained. This proved not to be the case, however, as the first slip occurred at 6 200 lbs.

After these tests were completed we attempted to break one of the reinforcing bars, but without success, the capacity of the testing machine being only 100 000 lbs. The maximum load on the bar was 98 000 lbs., the yield point being apparently at about 86 000 lbs. It was decided to use three of the large clamps on each splice, expecting to develop thereby about 15 000 lbs., which is about two thirds the working load on the bars, thus relieving the concrete largely of stress.

The placing of the clamps was carefully watched by the inspector, the nuts being tightened up with a 24-in. wrench. The cross heads used were $\frac{3}{4}$ -in. by $1\frac{3}{4}$ -in. steel bars, as these were found to be less expensive than the cast-iron and apparently about as effective. The U-bolts were of $\frac{3}{4}$ -in. steel with $1\frac{5}{8}$ -in. by $3\frac{3}{4}$ -in. clear opening, the length of bar being 13 ins. with $2\frac{1}{4}$ -in.

thread. The complete clamp weighed nearly $3\frac{1}{2}$ lbs., and cost 25 cents each. The tests were made in the Mason Laboratory of the Sheffield Scientific School, by Dr. W. K. Shepard and the writer.

In addition to this, the concrete in front of the splice was thickened so as to give a greater area for carrying stress. The concrete for these walls was mixed to a mushy consistency, using 1-in. stone and 1 : 2 : 4 proportions. The exposed surfaces were rubbed up in a manner similar to the outside wall, so as to leave a rough finish without board marks.

TUNNELS.

The 30 Spectators' Tunnels are 7 ft. high and 8 ft. wide, and average about 140 ft. in length. The design is as shown in Fig. 2. They are paved with 6-in. granolithic pavement and each is lighted with five 100-watt incandescent lamps. The side walls and roof are reinforced, the walls being 15 ins. thick and the roof running from 8 to 15 ins., according to the load. The method of construction was to build the footings of the side walls first, then the side walls and then the roof. Contraction joints were constructed about every 30 ft. of the length of the tunnels. The roof was waterproofed by three layers of Barrett Specification tarred roofing felt and one layer of tartex, mopped with pitch between each two layers and on top. This waterproofing was carried down the sides to a point below the bottom of the roof slab. The side walls were smoothed up with mortar or grout and then given one mopping of pitch. This work was done very well, and leaks have occurred in extremely few places. A layer of mortar, 1 in. thick, was placed over the waterproofing on top of the tunnels as a protection during backfilling.

The Main Tunnel and Players' Tunnel were built in a similar manner to the Spectators' Tunnels, the Players' Tunnel being 10 ft. wide and 8 ft. high, with sides 18 ins. thick and roof from 9 to 24 ins. thick, while the Main Tunnel is 15 ft. wide and 10 ft. high, with sides 18 ins. thick and roof 12 to 32 ins. thick. The floor of the Main Tunnel, which was intended for vehicular traffic, is 8 ins. thick, with the surface scored in 5-in. squares.

The inclination of this tunnel is 6.3 per cent. from the horizontal, while the Spectators' Tunnels are built on different inclinations from 0.2 per cent. to 4.3 per cent. The Main and Players' Tunnels are waterproofed in a similar manner to the Spectators' Tunnels. The Main Tunnel carries a load of 32 ft. of earth on its roof in the deepest place, and a sewer drain was laid through this tunnel at a depth below its inside bottom varying from 7 ft. at the inner end to 20 ft. at the outer end. No settlement of the side walls due to the sewer trench was noticed until 27 ft. of the fill had been placed over the tunnel, when settlement began and continued for several weeks and then stopped. The maximum settlement was about $\frac{3}{4}$ in. This was manifested in a sliding at the contraction joints, but caused no cracks affecting the strength of the structure. The water pipe serving the interior of the structure is carried through this tunnel in a trench built in the concrete floor so that, in case of any possible breakage, no harm can come to the tunnel or to the embankment above it. This trench is covered by a reinforced concrete slab and has the same appearance as the remainder of the tunnel. The inner ends of all tunnels are surrounded by heavy parapet walls, 15 ins. thick, thus carrying out the idea of massive simplicity characteristic of the entire structure.

SEATING STRUCTURE.

The seating structure consists of reinforced concrete slabs placed directly upon the embankment, on which are placed wooden benches supported by steel standards. The concrete is placed in the form of steps, and in small independent blocks. These blocks are, except at the cross aisle, three steps, or $7\frac{1}{2}$ ft. wide, and of varying lengths not usually exceeding 13 ft. and running from this down to 9 ft. A few such slabs were built up to 17 ft. in length. The slabs are $6\frac{3}{4}$ ins. thick at the minimum section, reinforced both top and bottom and in both directions in such a manner that they will support themselves if the sand underneath settles so that they rest on two edges, or are supported in the middle with two edges unsupported. (Fig. 3.)

The reinforcing was made up in mats, one for the top of the

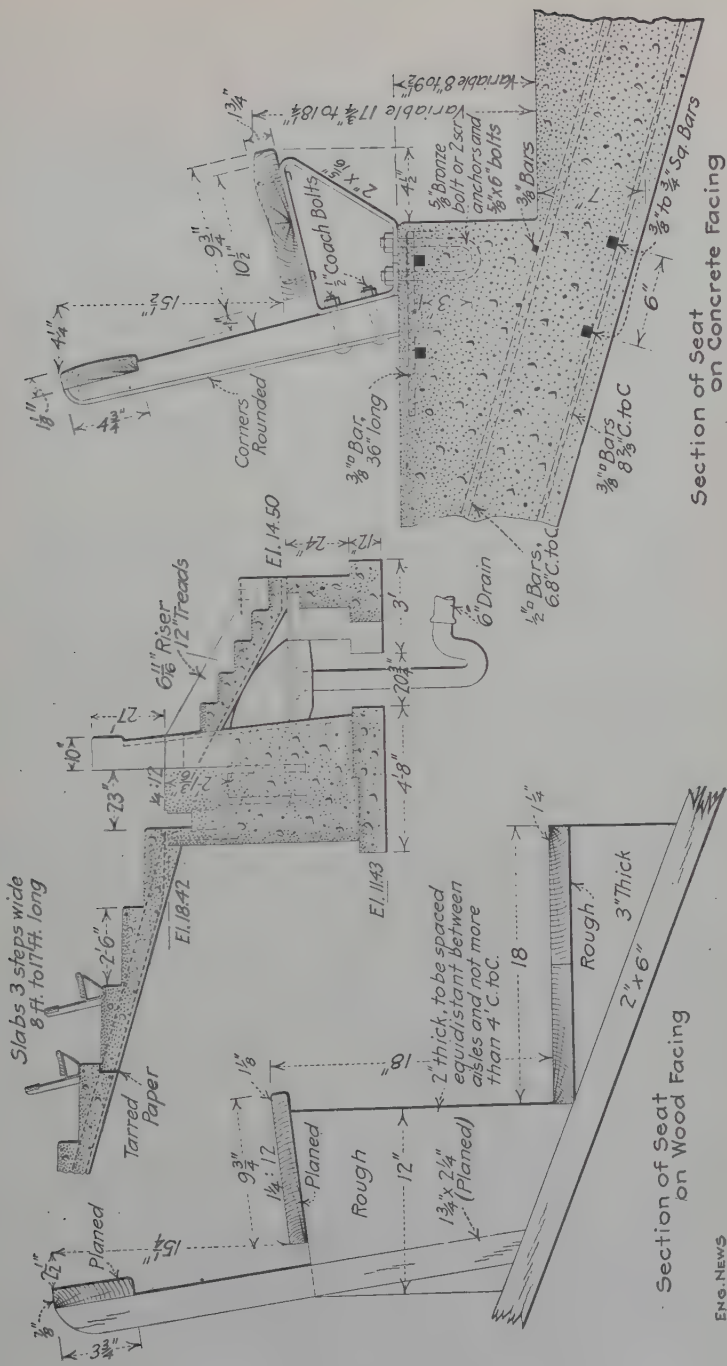


FIG. 3.

slab and one for the bottom, while the bars running through the corners of the steps were placed separately. Special reinforcement was used around the bolts for holding the seat standards. Havemeyer bars were used entirely in the reinforcing work. Tarred paper was used to separate the blocks along the circumferential joints, and the radial joints were coated with tar. An expansion joint was provided in the center radial joint between each pair of tunnels. This consisted of a sheet of Carey's "Elastite," a material made up for joints in concrete pavements by placing a layer of bituminous material between two layers of tarred felt, the whole being $\frac{3}{8}$ in. thick and quite elastic. The sheets were cut at the mill to fit the steps.

The concrete was given a $\frac{1}{2}$ -in. mortar finish on both treads and risers. The mortar was colored with lamp black to a dark blue stone, so as to relieve the glare. This finish was placed integral with the concrete and troweled to a smooth, hard surface, the forms being removed from the risers as soon as possible, and before they had reached a hard set. The blocks were placed alternately on the checkerboard system, it being necessary in order to make the speed required that they should be placed alternately up and down the slope as well as in horizontal lines. The aisles were given a surface treatment of the concrete hardener made by the Trus-Con Laboratories. The average day's run when working to good advantage was about 30 blocks, or nearly 100 cu. yds. This was done with a force of about 30 men and 3 horses on mixing and placing, and about 17 finishers and 9 helpers on the finishing. The finishers worked until all of the treads were finished on the blocks put in each day. The risers of blocks placed in the afternoon were left until the following morning before finishing.

TEMPORARY WOOD FACING.

The concrete facing was carried only up to the approximate level of the original ground, so as to allow time for the embankment to settle, but the full seating capacity was provided by placing temporary seats on the bank above the concrete. Two in. $\times$ 6-in. wood sills were laid up and down the bank, the 3-in.

wedges placed on these and foot boards nailed to the wedge blocks. The seats were built of 2-in. $\times$ 12-in. uprights, 1 $\frac{1}{4}$ -in. $\times$ 10-in. seat boards, 1-in. $\times$ 4-in. back boards supported on 2-in. $\times$ 2 $\frac{1}{4}$ -in. standards, all dimensions given being in the rough. The seat boards, back boards and back standards were planed.

The treads of the steps were all 30 ins. wide, more space than usual being necessary on account of the seat backs. The clear space between the back of one seat and the front of the next is 15 $\frac{1}{2}$ ins., giving sufficient room so that as a rule people can pass in front of those sitting without causing them to rise.

CONCRETE.

The concrete aggregate was broken trap rock, obtained from a quarry about two miles north of the Bowl, and sand obtained from the excavation. The cement used was Nazareth Portland cement, furnished under the autoclave test. The proportions used in the reinforced concrete retaining wall and in the seating structure were 1 : 2 : 4 with 1-in. stone; in the outer and inner retaining walls and tunnels the proportions were 1 : 3 : 5 with partly 2-in. and partly 2 $\frac{1}{2}$ -in. stone.

The plant used for most of the tunnels was located in the center of the Bowl, with radial track running to the individual tunnels, the cars being hauled up on top of the tunnel forms. The plant for most of the outer retaining wall was located on the site of the Smaller Gate House, the mixers being elevated and discharging into cars running on a trestle built outside of the wall. The walls and tunnels adjacent to the Main Gate House were put in from a plant located on the site of the Main Gate House and consisted of a Marsh-Capron 1-yd. mixer, hoisting tower and chutes. The same plant was used for the inner retaining wall and the concrete seating structure by laying a track around the interior of the Bowl just above the inner ends of the tunnels and chuting the concrete from the tower into cars on this track, and from the cars into place.

PERMANENT SEATS.

Considerable study was devoted to the permanent seats, and the design adopted was a wooden bench consisting of a

plank supported on the edge of the concrete step by overhanging galvanized steel brackets, and provided with a back board supported by wooden standards attached to the same brackets. The amount of the overhang is $4\frac{1}{2}$ ins., giving ample room for sliding the feet underneath. The brackets were attached to the concrete by bolts, $\frac{5}{8}$ -in. bronze U-bolts being used over the larger part of the structure, although the Richmond Screw Anchor and $\frac{5}{8}$ -in. sherardized bolts were used on a part of it. The bronze U-bolts were of Tobin bronze and were annealed to prevent as far as possible breakages due to initial strains in the metal. All steel was galvanized and was given three coats of Billings-Chapin & Company's "Rostnicht," the last coat applied after the seats were completed.

The steel standards were supported on wooden wedges until the benches were completed and both seat planks and back boards lined up, and were then grouted with Portland cement mortar, mixed 1 to 2. The grout was not allowed to dry out, but was kept moist for at least a week after being poured.

The top of the seat is hollowed out in a special curve, to give greater comfort, and the front of the back is rounded. This shaping of the wood is a special feature, never before attempted on such seats so far as known, and is expected to add greatly to the comfort of the occupants, a matter of no small importance when it is considered that a large portion of the spectators will occupy their seats for three to four hours. This was secured without expense by being done in the mills when the boards were first planed, it being nearly as easy to plane the boards with curved knives as with straight knives. Many experiments were made to determine just what curves were best for the seat and the back boards, and just the proper angle at which these should be placed to give the greatest comfort to the average human being, and the result has been most favorably commented upon.

The lumber used was Douglas fir from Oregon, and was selected especially for the reason that vertical grain wood could be obtained, thus almost entirely eliminating splintering up of the seat boards. It was found upon investigation that vertical grain lumber could be obtained in only three woods: Douglas

fir, western hemlock and Noble fir mixed, and redwood. The western hemlock and Noble fir, which are similar woods and are as a rule supplied together as one kind, could not be gotten out in sufficient quantities to supply our needs in the time available. The redwood was eliminated on account of its liability to stain clothing when wet. The Douglas fir seemed to possess the good qualities required and to be nearly as durable as redwood, and stronger. The only objection to it is the occasional occurrence of pitch pockets. These pitch pockets can be practically done away with by kiln drying the wood, the pitch being boiled out during the process, and this method was adopted with very satisfactory results.

The lumber was supplied by the Eastern and Western Lumber Company, of Portland, Ore., through their local agents. The question of what, if any, preservative to use on the lumber was given much study, it being desired to keep the natural beauty of the wood, and hence to use either oil or varnish rather than paint. There was not sufficient time available to make long time tests on these materials, but samples of the wood were coated with several oils and varnishes and exposed to the weather for a few weeks, and such observations as were possible made upon them. The oils used were linseed oil and three different brands of prepared china wood oil. Three brands of spar varnishes were also used. The linseed oil was rejected because it left the surface of the wood rough and in a condition to catch dirt so that the boards assumed a dingy appearance, which was not desirable. One of the brands of prepared china wood oil had much the same effect, but the two other brands seemed to be very good, and dried with a gloss about like a very thin coat of varnish, and seemed to fill the pores of the wood, leaving a smooth hard finish which resisted sticking of dust, and was easily cleaned. Two of the spar varnishes gave a similar result, but cost between three and four times as much, and there seemed to be some doubt amongst the makers as to whether any spar varnish would stand the severe exposure to which these seats would be subjected, and last a sufficient length of time to make it pay to use them. The comparative cost of the china wood oil and the high-grade varnish was about 75 cents and \$2.50 per

gallon respectively, and the spar varnish was more difficult and more expensive to apply. While we were unable to find any similar place where china wood oil had been used, still it is well known as the base of waterproofing paints and spar varnishes, and the indications seemed to be very good that it would prove to be about as durable as spar varnish in this location, and at any rate would waterproof and preserve the wood as well as anything, and would furnish a good foundation upon which to apply varnish or paint later if it proved that one of these would be better. The final decision was to use two coats of china wood oil, using the two brands which seemed on the preliminary test to be satisfactory. The first coat was applied before the seats were put in place and the second coat afterwards.

A number of seat planks in the most exposed places were coated with various combinations of the oils and varnishes noted above, and a record kept so that by the time the remainder of the permanent seats were placed, or when it became necessary to recoat those already placed, we might have the benefit of long time tests on all of the materials which seem most likely to give good results. At the end of one year the sample planks were carefully examined and it was found that none of the oils and varnishes had withstood the weather, the sample coated with the china wood oil being fully as good as any. The summer sun seems to be the test which none of the coatings will stand. As the seats were in need of further protective coating, they were again coated with the china wood oil on the upper surfaces. The surfaces which were not exposed to the sun were in as good condition as when originally done.

The temporary seats were not oiled, as it was expected that they would be used only for one game.

SEATING CAPACITY.

The total number of seats is 60 815 in the main structure, with 244 in the press stand, making a total of practically 61 000. Owing to the great demand for seats at the opening game, a special temporary stand was erected on the promenade around the top of the Bowl, giving an increase in capacity of 7 522 seats, making the total capacity about 69 000, which is

believed to be very much larger than ever before attempted. The space allowed for each person averages about 18 ins., the minimum space being $17\frac{3}{4}$ ins.

PRESS STAND.

The press stand seats 244. It was erected at the middle of the west side at the top of the bank, where there could be a special stairway to the outside so that messengers could be sent back and forth without disturbing the spectators. This was built entirely of wood, and high enough so the reporters could write their descriptions on the table provided, without danger of the spectators in front of them cutting off their view by standing up. Two rows of tables and benches were provided, with standing room for messengers and assistants. Adequate telephone and telegraph facilities were also installed.

Behind the press box a special stand was erected for the photographers, accommodations for 40 being provided. This consisted merely of a platform with table sloped towards the field so that cameras placed directly on it would be pointing at the center of the field. The table was omitted at one point so that circle cameras could be set up on tripods.

ARCHITECTURE.

The architectural features of the Bowl are exceptionally effective in their remarkable simplicity. The purely architectural features are the Main Gate House which faces the junction of Chapel Street and Yale Avenue, and its complement, the Smaller Gate House, on the opposite side of the Bowl. Neither gate house has yet been built, and the following information is taken from the drawings. The Main Gate House is to be 96 ft. $\times$ 47 ft. in plan and 42 ft. high. The ground floor is a large lobby leading to the Main Tunnel, the main approach to an exit from the playing field. Stairs lead to the second floor, where ample quarters are provided for the home team and for the ticket department.

This building will be flanked on either side by massive stairways leading from the top of the embankment to the ground

below. These are intended to be used as an exit for people walking around the promenade after the games.

The Smaller Gate House is to be 60 ft. $\times$ 43 ft. in plan and 27 ft. high. The ground floor is a lobby leading to the Players' Tunnel, which also leads to the playing field. Stairs give access to the second floor, where quarters are provided for the visiting team.

These buildings are designed in a free adaptation of a Roman style of architecture, and set off the rest of the Bowl in an appropriate and pleasing manner.

FLAGPOLES.

The only decoration of the Bowl on the day of the first game consisted of two large flagpoles, from one of which a Yale flag was flown and from the other a Harvard flag. This further carried out the general idea of simplicity, and made a very effective finish to the structure.

WATER SUPPLY SYSTEM.

The water supply is obtained from the mains of the New Haven Water Company by a 6-in. cast-iron pipe running from Chapel Street into the interior of the Bowl. Four-inch cast-iron lines supply water to eight 3-in. Ludlow flush hydrants around the playing field. A 4-in. line is laid entirely around the outside of the Bowl, with 2-in. outlets opposite each tunnel entrance.

DRAINAGE SYSTEM.

The drainage outside of the Bowl is taken care of by merely sloping the land to the adjacent streets. The outside slope of the embankment drains to a gutter in the top of the outside wall, and running through a pipe laid in the wall to a drain around the outside. This drain is 8 and 10 ins. in diameter and connects into the main drain in front of the Main Gate House. The inside slope of the embankment drains over the concrete to a gutter in the top of the inside retaining wall, outlet being given at each aisle by a short pipe discharging beneath the

steps leading to the field. The water is received on a concrete slab occupying the whole space under the steps, from the center of which a drain pipe leads to the drain laid around the field, concentric with the retaining wall. This pipe around the field varies from 8 to 12 ins., and then discharges into the main drain, which is laid across the short axis of the ellipse. The main drain increases from 15 to 24 ins., and discharges into the West River. The water which falls on the playing field drains towards the retaining wall around the field, reaching a sod gutter next to the wall and discharges on to the concrete slab under the steps and thence into the drains, as noted above. All drain pipes are of vitrified clay tile. All drain inlets are covered with a pyramidal cast-iron grating. So far, the drainage system has worked perfectly, except for a few stoppages in small pipes due to construction.

PLAYING FIELD.

The playing field had to be built on a pure sand foundation, 28 ft. below the natural surface of the ground, and to be put in shape to play upon less than three months after it was completed. The first problem was to so construct the field that sufficient moisture would be held in the loam to prevent the grass from burning out. This was done in two ways: first, by using 18 ins. of black loam; second, by harrowing into the top three inches of loam an inch of fertilizer humus, a natural leaf mold obtained from East Lexington, Mass., to which certain fertilizing chemicals had been added. This humus has the property of retaining moisture a long time.

The next problem was to see that water from rain storms would not stand upon the field so as to interfere with the playing. This was met by crowning the field slightly, the center of the field being made 12 ins. above the turf at the walls, 5 ins. of this crown being between the center of the field and the side lines of the gridiron, a distance of 80 ft. This shape was effected by a special design which gives as rapid a slope as possible near the center of the field without using a straight grade from the center to the sides, which is liable to settle so as to produce hollows. The shape adopted has worked out very satisfactorily,

the water draining away with sufficient rapidity and there being no hollows which collect water. At the same time the slope is not sufficient to be noticeable to the eye or to the players.

The field was built with great care, sub-grade being smoothed up 18 ins. below the finished grade and 8 ins. of black loam being then spread and rolled with a 5-ton roller. Sufficient loam was then put on to roll down to just under 17 ins. above sub-grade, and the surface was then trimmed and rolled to a uniform depth of 17 ins. An inch of fertilizer humus was then placed and harrowed in with a cut-away disk harrow, and raked with hand rakes until smooth and fine. A 2-in. layer of turf was then placed and rammed to a firm bed, and screened loam and compost was scattered over the surface, raked in and seeded lightly. This work was done during August, and the field was left to itself, except for watering and cutting grass, until the end of October, when a 5-ton roller was put over it before any football practice was allowed. Light practice was held several times during November, but it was not possible to use the roller again on account of the large amount of rain. The above description applies to the playing field except for a space 25 or 30 ft. wide next to the inner retaining wall, which was necessary to reserve as working space for the contractor. This part of the field was completed and turfed about the first of November. A good proof of the value of the design and the care with which the work was carried out was found in the condition of the field when the first game was played, November 21, as two storms with a total precipitation of 3 ins. had occurred during the preceding week, the second stopping only about thirty hours before the game was played, yet the field was in good condition over seven eighths of the area, the other one eighth being slightly soggy, probably because it had not previously been thoroughly soaked. No trouble was found in securing a good, healthy growth of turf without an excessive watering.

TOILET FACILITIES.

Realizing that a crowd of 70 000 people at some distance from regular toilet conveniences would need a considerable

amount of such facilities, 8 temporary buildings were erected, 4 each for men and women, providing accommodation for 500 men and 100 women at a time. Conspicuous signs were placed upon the roofs, and their location was shown plainly on the plan sent out with the tickets showing the field and its surroundings. The crowd seemed to appreciate the facilities and they were used extensively. The women's toilets, especially, about which there had been some question, were used by actual count by 5 000, and men's toilets by a much larger number, but no attempt was made to count the men.

WALKS.

The original plan contemplated a concrete promenade on the top of the embankment and a concrete walk around the outside to give access to the various tunnels. For the present, however, it was decided to use a broken stone walk in both places, and this was designed to be 2 ins. thick, of $\frac{3}{4}$ -in. stone, to be rolled and then sprinkled with stone dust so as to fill the voids. Placing this thin layer of broken stone directly upon loose sand and gravel seemed somewhat hazardous, but as it was likely to be replaced by concrete later it was desired not to put more expense into it than was necessary. The walk has proved very successful, however, so much so that when left unguarded after the game it became used as an automobile speedway, and prompt measures had to be taken to stop this traffic or the walk would soon have been destroyed.

EXTERIOR GRADING.

The elevation of Chapel Street north of the Bowl made it desirable that the ground between the Bowl and the street should be cut down about 10 ft., and also to a considerable depth between the Bowl and Yale Avenue. Yale Avenue was graded as part of the contract work, and was surfaced with about 3 ins. of yellow loam, which bound the gravel together and gave a fairly good surface after it had been rolled several times. Between these streets and the walk around the Bowl 18 ins. of loam was placed, 12 ins. of yellow and 6 of black, ready to be



FIG. 4.

seeded down to form a grass plot. The surplus material from the Bowl and the surrounding grounds was carried east of Yale Avenue to a meadow between the high bank and the rectified channel of the present river, where a space of some twelve acres was converted from swamp into good land, which is intended to be used eventually as a parking field for automobiles. This could not be so used the first year, as there was not sufficient time to grow grass upon it, although 6 ins. of loam was put over the surface for this purpose. The rains which occurred just before the game softened the surface of the ground too much to permit parking machines on it. This ground is available not only for parking automobiles, but for all kinds of athletic purposes, and will doubtless be so used. The natural drainage from the hill towards the river tends to make the meadow too wet, and this was taken care of by laying agricultural tile drain at the bottom of the bank and connecting it to the river by two lines of 8-in. vitrified pipe. Since this was laid, there has been no trouble with water on the meadow except from such as fell directly upon it.

CONTRACTS.

The work was divided into three contracts, the first covering the general earthwork, grading, concrete except seating structure, and construction of playing field. The second contract covered the seating structure, both permanent and temporary, and toilet buildings. The third contract covered the loaming of the area outside the Bowl, the macadam walks and drains on the meadow.

PERSONNEL.

The Bowl, as far as built, was completed during 1914, the work being done under the Yale Committee of Twenty-One, Incorporated, T. De Witt Cuyler, chairman, and the construction being directly in charge of the Structures Committee, David Daggett, chairman.

Several plans were offered the committee, that suggested by C. A. Ferry of New Haven being accepted. James B. French, of New York, was appointed consulting engineer in charge of

design and construction, and the first contract was prepared under his supervision. Mr. Ferry was appointed resident engineer. Mr. French resigned in September, 1913, and Edward G. Williams, of New York, was appointed advisory engineer, and has acted throughout in a consulting capacity. Donn Barber, of New York, was consulting architect. In December, 1913, the author was appointed construction manager (later changed to supervising engineer), to take active charge of the work both of design and construction.

All three contracts were let to the Sperry Engineering Company, of New Haven, A. William Sperry, president, and Geo. H. MacLean, treasurer. Mr. MacLean also acted as general superintendent of the work.

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MOSQUITO EXTERMINATION IN PANAMA AND NEW
JERSEY.

BY HAROLD I. EATON.*

(Presented before the Sanitary Section, November 24, 1915.)

THE history of mosquito extermination begins properly with the occupation of Cuba by the United States troops during the Spanish-American War in 1898.

The occupation had lasted only a short time when it was found that the ranks were depleted more by fatal sicknesses than by casualties caused by actual warfare. The most prevalent and the most fatal of these sicknesses was found to be yellow fever, and the members of the American Medical Corps who accompanied the troops immediately began investigations as to its cause. It is unnecessary here to go into a detailed account of these various experiments, as accounts have been published in various journals giving all details of their investigations. The results furnished indisputable evidence that yellow fever was and could be transmitted only by the *Stegomyia* mosquito, and that transmission was by the transfer of the germ from the blood of a person suffering with yellow fever to another person. Subsequently similar experiments were conducted in the study of

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the cause of malaria, and it was again found that the mosquito was the only carrier of this disease, the only difference being that mosquitoes of the *Anopheles* species carried malaria in the same manner that *Stegomyia* carried yellow fever.

An exhaustive study of the breeding habits of mosquitoes was at once made and a general clean-up of Havana and its environs was entered upon. Col. W. C. Gorgas was at the head of the Sanitary Corps which undertook the work, and the results obtained by the elimination of mosquito-breeding places and of mosquitoes within a radius of several miles of Havana accomplished unexpected results. Yellow fever in a short time was so reduced that it could no longer be called a menace, and equally pleasing results were obtained in the campaign against malaria. Subsequently the same methods were used in the fight against yellow fever in New Orleans during its epidemic.

Shortly after the United States had definitely entered upon a plan of building a canal across the Isthmus of Panama, Colonel Gorgas was detailed there as chief sanitary officer. It was known that enormous losses had been suffered by the French forces of construction during their attempts at canal building, and that Panama was considered one of the most unhealthful countries in the western hemisphere on account of the extreme prevalence of yellow fever and malaria. It was, therefore, planned to start sanitary operations immediately in order that conditions might be as healthful as possible before any large number of recruits were sent from the United States. Operations started in the fall of 1904, and sanitary measures were taken at points where it was planned that construction should commence. On account of the difficulties of organization and in securing labor, progress was slow the first few months, so that in 1905, when actual building operations were undertaken, yellow fever had not been completely eradicated. In April of 1905 so many Americans were stricken with yellow fever that there was a panic among them to leave the Isthmus. Hundreds did leave, but those who remained saw the end of the yellow fever on the Isthmus in May of 1905, when the last case occurred. In the eleven years since that time, no case of yellow fever has originated on the Isthmus of Panama. After the first two

years, malaria was reduced to one fourth of one per cent. among the employees, whereas in the early days of construction, sickness due to malaria of ten per cent. of employees was not uncommon. The method used, of course, was the extermination of mosquitoes by the draining of swamps, screening of water barrels, cleaning and oiling of ditches and stocking of ponds with fish. The cost was large on account of the necessity of active operations during the entire twelve months of the year. Much permanent work was done in installing complete and effective drainage systems. Where it was shown that the cost of maintenance was high enough to warrant it, ditches were lined with concrete, and troublesome streams were diverted into pipes or concrete channels.

The earliest attempts at mosquito extermination in the United States were probably undertaken in the northern part of New Jersey, in the year 1901. At this time, Prof. John B. Smith, of the New Jersey Agricultural Experiment Station, had commenced a study of the habits of the mosquitoes found in New Jersey and had recommended to several cities the various methods of extermination. The town of South Orange appropriated \$1 000 for mosquito extermination in 1901, drained several surrounding swamps and carried on inspection work within the limits of the town with a view to eliminating all breeding places. It was confidently expected that excellent results would be obtained, but unfortunately the habits of the salt-marsh mosquito were not then fully known. It had, of course, been established that the mosquito breeds only in water and that from six to ten days elapse between the time the eggs are laid to the emergence of the winged mosquito. The "wrigglers" seen in rain barrels and pools of water had been identified as larvæ of the mosquito, but little was known of the habits of the adult, its range of flight, etc. It was commonly believed that the mosquito lived only a few days and that it flew very short distances from its breeding place. After spending the money appropriated for local work, the people of South Orange were, therefore, immensely surprised to find the town filled with mosquitoes during the early days of June. This condition continued sporadically throughout the summer

months, and mosquito extermination suffered a considerable set-back on account of the inability to obtain results.

Professor Smith continued his investigations, however, and in 1903 determined that the portions of New Jersey within twenty miles of the coast which was bordered by salt marsh suffered from migrations of varieties of mosquitoes bred only in the pools existing on the salt marsh. Two varieties of mosquitoes, known as the *Aedes cantator* and *Aedes sollicitans*,



FIG. 1. THE WHITE-BANDED SALT MARSH MOSQUITO.
(*Aedes Sollicitans*.)

were bred in the greatest numbers, *cantator* being the most troublesome in the early part of the season up to July, when *sollicitans* predominated, the *cantator* gradually disappearing until late in the fall. *Aedes sollicitans* is more widely distributed than the *cantator*, being found in large numbers in Delaware, South Jersey, New York and Long Island. (Fig. 1.) This mosquito has very distinctive markings, consisting of broad white bands around the middle of the proboscis and longitudinal stripes along the back. The mosquitoes of both the above-named varieties breed only on the salt marsh. As stated

before, upon reaching the winged stage they migrate for long distances inland, in some cases as far as thirty-five miles, and for this reason the efforts of mosquito extermination in the cities of northern New Jersey proved unavailing, as only the locally bred mosquitoes were eliminated.

New Jersey has approximately 300 000 acres of salt marsh along its coast, extending from Newark Bay on the north down to the extreme point of Cape May and on up the eastern shores of Delaware Bay, the only break in its continuity being about centrally located on the Atlantic seaboard below Sandy Hook.

Professor Smith conducted a careful investigation of the best methods for eliminating the breeding on the salt marshes and advocated a drainage system consisting of narrow ditches 10 ins. wide and 30 ins. deep for draining the water from the surface of the marshes. Subsequent improvements dealing with the arrangement of ditches and the use of dikes have been made since the death of Professor Smith, but the principles of the method advocated by him are in use.

In 1906 the New Jersey legislature passed a law appropriating \$300 000 for the drainage of the salt marsh in the State of New Jersey for the elimination of mosquito-breeding places, placing the work in the hands of the New Jersey Agricultural Experiment Station. Unfortunately the entire sum was not appropriated at once, only a small appropriation being made annually by each legislature and the amount of each yearly appropriation left to the discretion of each legislature. Under this system up to 1912 about \$110 000 had been expended for the drainage of the marshes, and in amounts varying from \$5 000 to \$30 000 annually. The work was started in North Jersey on Newark Bay and carried down the coast for a distance of forty miles. Complete drainage systems were not installed, however, as it was hoped that enough interest would be shown by neighboring communities to appropriate amounts sufficient to complete the drainage within that vicinity. This was not done, however, and the full benefits of the work were not secured.

In 1912, another bill was passed by the legislature creating in each county in New Jersey, by appointment of the Supreme Court Justice, a commission of six men whose duty it should be to carry on the work of mosquito extermination in each county with funds raised by taxation. The Director of the New Jersey Agricultural Experiment Station was given oversight of the work in all counties, and given the power of deciding whether or not the work would be of sufficient benefit to a county to justify the formation of a commission and the raising of funds. The amounts which could be raised in the different counties depended upon the density of the population and the amount of resources. In a populous county of over 500 000, the law provided a rate of one eighth of a mill for each dollar

of assessed valuation, the amounts thus varying, so that a county of a large area and small population could raise money at a rate of one-half mill on each dollar of assessed valuation. In Essex County, probably the wealthiest county in the state, it was possible to raise, under this law, \$75 000 annually for the purpose of mosquito extermination, and in the smaller counties the amounts varied from \$10 000 to \$35 000. Several counties immediately took advantage of this act to form commissions, prosecuting vigorous campaigns comprising both drainage of the salt marshes and the elimination of fresh-water breeding places.

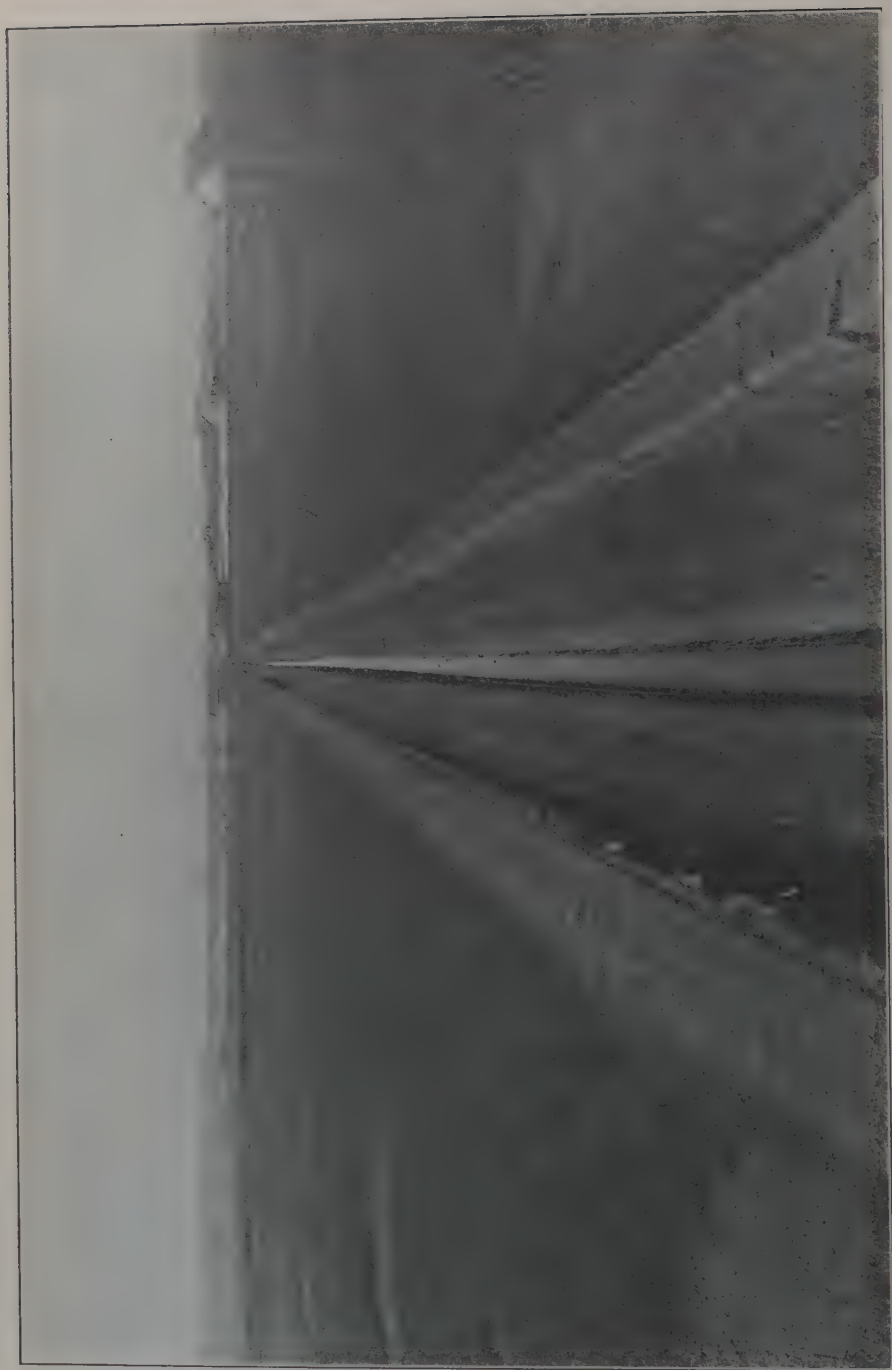
In Atlantic County, in the southern part of New Jersey, a commission was formed in 1913 with power under the law of 1912 to obtain \$31 000 annually for carrying on its work. Twenty-six thousand dollars was decided upon as the annual appropriation which would suffice for the work, and drainage of the salt marsh was immediately started. This commission has been in existence three years, and during that time has drained more than 12 000 acres of the 50 000 acres along its coast line. On account of tidal conditions, it has been found that 20 000 acres of this 50 000 will not require drainage, so that there remains to be drained about 18 000 acres. Each summer a corps of inspectors has been organized for locating breeding places of the fresh-water mosquito within the various cities and towns, and the recognized methods of drainage and oiling for their elimination have been used.

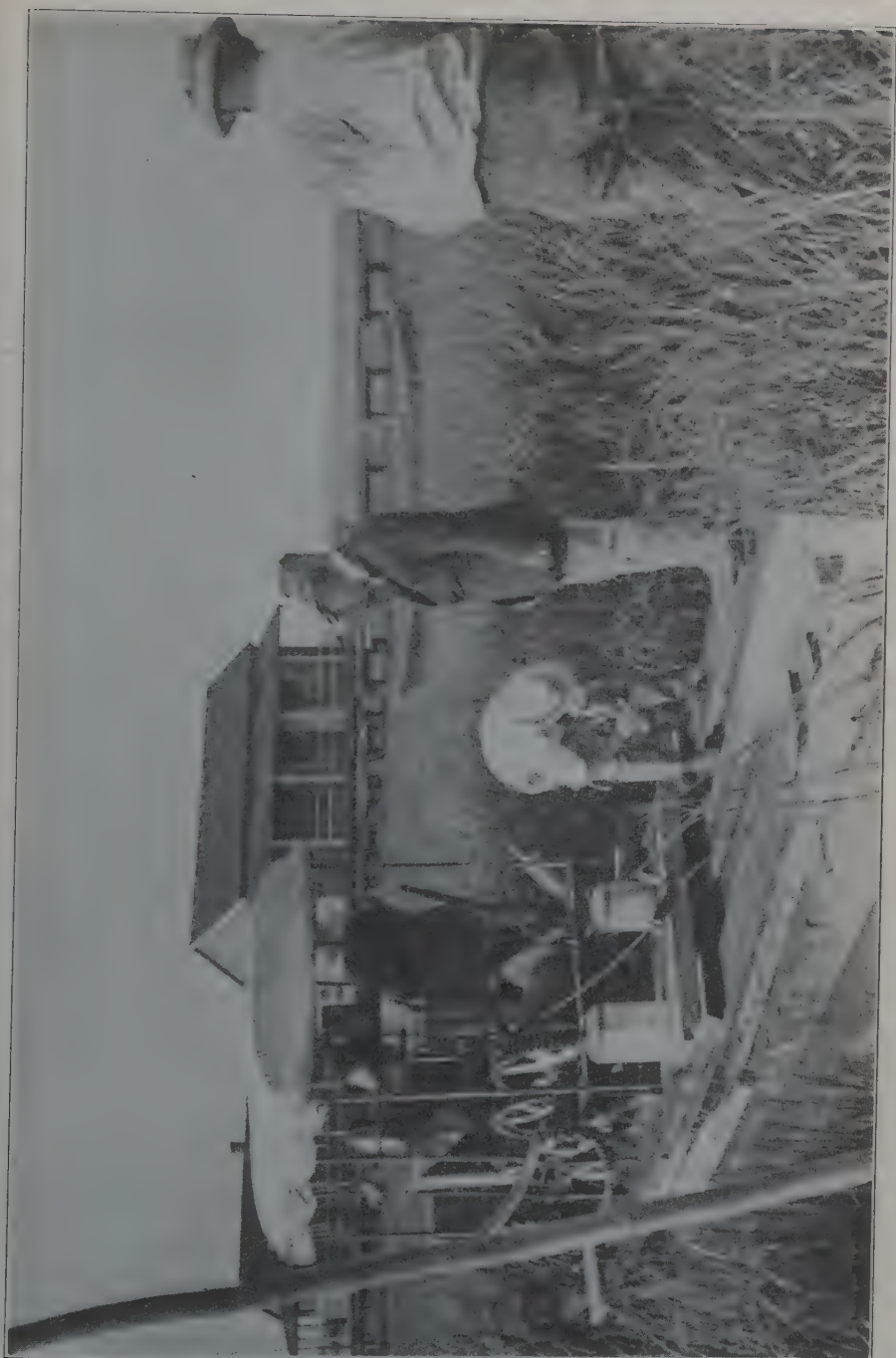
The salt-marsh mosquito, however, is the great problem of Atlantic County and of South Jersey, with the fresh-water problem occupying a place of much less importance. The breeding habits of the salt-marsh mosquito vary from those of the fresh water to a great extent. The female mosquito of the salt-marsh variety lays her eggs in the depressions on the meadow, in the mud around the edges of pools or in the bottom of dry depressions. When these eggs are covered by water of sufficient warmth, the "wrigglers" appear from twenty-four to forty-eight hours later, their growth depending on the weather and the resulting temperature of the water. In the warm weather of July and August the winged mosquito emerges from the pool

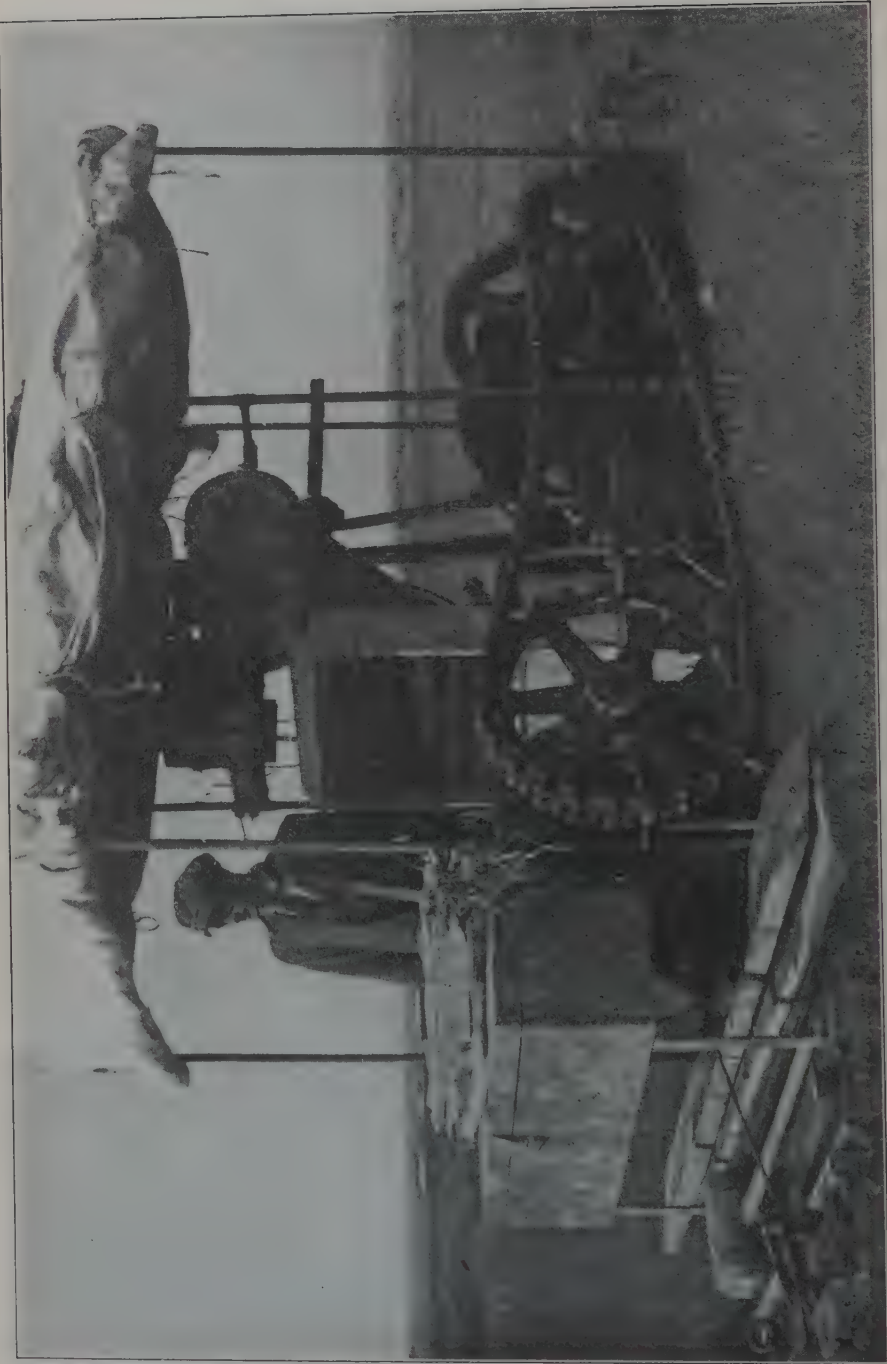
in from six to eight days, while the time required in the colder weather of spring and fall may be as much as four weeks. As the eggs are all covered with water and hatch into "wrigglers" at the same time, the mosquitoes emerge days later at practically the same time, ninety per cent. of them appearing on the same day. This is the cause of a sudden and overwhelming "crop" of mosquitoes appearing in a community which may have had none the day before. As stated above, the salt-marsh mosquitoes fly with the light winds across the country adjacent to the marsh and can be found at any time during the season twenty-five or thirty miles from the nearest breeding place.

The drainage of the salt marsh being carried on by this commission is performed with the sole object of removing from the surface of the meadow, by effective drainage, the stagnant water in which the mosquitoes breed. The drainage system usually consists of a series of parallel ditches, placed from 125 to 200 ft. apart, this distance depending on the nature of the soil and vegetation, which determines the porosity of the meadow and its adaptability to drainage. A deep creek or stream is used as the outlet of the ditches to insure the emptying of the ditch at low tide. Where a natural creek is not available, and where the bay shore is too far away, an outlet ditch is dug 20 to 30 ins. wide and 30 ins. deep. As it requires at least seven days for the eggs to become mosquitoes, the drainage system is planned to remove the water from the surface within three days, so that the "wrigglers" cannot hatch into mosquitoes. Each ditch drains the meadow on each side of it for a distance of 60 to 100 ft. Where a deep pool or depression is found, a short spur ditch is dug from the pool to the nearest ditch. This allows the tide to flow in and out, insuring a constant change of water and giving admission to the small minnows which feed on mosquito "wrigglers."

Several varieties of implements have been used by the commission in the digging of these "mosquito ditches." The first method employed was the contract system, under which contracts were let in amounts of about 200 000 linear feet at prices varying from $2\frac{1}{4}$ c to $2\frac{1}{2}$ c per foot. The contractors, in performing the work, used patented spades operated by two







or three men. At one cut a spade would remove a block of sod 30 ins. deep and 10 ins. wide and about 10 ins. along the length of the ditch. A power machine was used by one of the contractors, which cut out sods in substantially the same manner and the same dimensions.

In 1914, the commission decided to do its own ditching with machines known as the Eaton Ditching Machine, the principle of which differed considerably from those of the implements then in use. With this machine the sods were removed in long continuous strips somewhat after the manner of a furrow cut by a plow, except that the strips were 10 ins. in width and 15 ins. in depth and the material of 30-in. depth removed at one cut and thrown on both sides of the ditch. Under this system the ditch cutters are pulled toward the hauling machine anchored 500 ft. away on the marsh, and, as the cutter travels at the rate of about 30 ft. a minute, 500 ft. are cut in fifteen minutes. The hauling machine then pulls itself ahead 500 ft. by the use of anchors carried ahead, and the operation is again repeated. In this manner the cost of ditching in Atlantic County has been reduced to about $\frac{3}{8}$ c. per linear foot and the funds of the commission have been sufficient to drain a much larger area than would have been possible under the more expensive contract method. The machine ditching is supplemented with hand ditching to complete the drainage in various areas, and the cost per acre for complete drainage under the present method has been found to average about \$4.00.

The results obtained by the drainage of only a portion of the salt marsh within the county have been better than anticipated, as certain localities which are about centrally located with regard to the drained meadow have been free from mosquitoes the greater portion of the season, receiving only occasional invasions of mosquitoes bred on the marshes several miles distant. It is not expected that complete results will be obtained until all the marshes within the county limits have been drained, and even then we may expect occasional invasions from the mosquitoes bred on the marshes of neighboring counties which at present are not drained. Indications are, however, that these marshes of the adjacent counties will be drained

either this year or next with funds raised within the counties, under the law of 1912, or with funds contributed by the state, remaining under the law of 1906. The work will require several years for completion, but the number of salt-marsh mosquitoes will decrease each year as the work is extended, and the results obtained when the work is finally completed will be well worth the time and money expended. Freedom from mosquitoes in Atlantic County and South Jersey will be of untold benefit both to the shore resorts and the agricultural communities, whose development is checked solely by the devouring summer hordes of salt-marsh mosquitoes.

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REFORM AND REGULATION.

BY ALEXANDER C. HUMPHREYS,* M.E., Sc.D., LL.D.

(Presented April 21, 1916.)

It is practically impossible to discuss any moot question of importance without being misunderstood. Those who strive to preserve the balance between two extremes are almost sure to be misunderstood and misquoted by the adherents of both extremes.

As far as possible, let me anticipate this difficulty, which stands in the way of a fair and reasonable discussion of the questions involved in the regulation of public utilities, by the statement of my proposition.

While, on the one hand, quasi-public corporations should be required to submit to regulation under governmental authority, on the other hand this regulation should not be so overdeveloped as to deprive the officers of these corporations of the opportunities to employ completely their initiative in the interests both of the investors and the public served. Undoubtedly, under the present-day conditions, the need for regulation had become apparent. A comparatively few of these public service corporations through their unwisdom had helped to create the demand for more onerous regulation; they developed in the public mind

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a spirit of antagonism which has worked to the injury and prejudice of the great army of corporations which are ready and willing to conduct their affairs for the best interests of all concerned.

To obtain the best result for all concerned, coöperation between the several interests is a prime necessity. No real coöperation can be secured where there is antagonism between the parties in interest. If one side is likely to be the aggressor, the other side must be prepared for defense.

Under an autocratic government both sides can be driven to work coöperatively in the interest of maximum economy and efficiency. But ours is not an autocratic government; theoretically, at least, it is a government of the people, by the people and for the people.

Are we not looking for more than is obtainable from a democracy? Should we not recognize that, for the liberties we enjoy, or are supposed to enjoy, under a democracy, we must pay a price in the sacrifice of some of the material efficiency which can be secured under an autocracy? This price must be paid, and always will have to be paid, so long as human nature is what it is. As in every other mundane problem, a balance has to be established between the advantages and disadvantages. But this does not mean that we should not be continually vigilant and persistent in our activities to bring the price down to the attainable minimum; particularly the effort should be to prevent the price from being increased with the years. While it devolves upon all the people to be keenly solicitous for the elimination of the bad and the development of the good in our civic and national life, we must avoid the error of believing that good intentions alone are a sufficient qualification for leadership in reform movements.

Those who confidently and light-heartedly assume the grave responsibility of undertaking to reform anything or everything which excites their disapprobation may, through their incompetence, easily develop other and more dangerous conditions than those which they have, perhaps honestly, been trying to correct.

The New York *Sun* in a recent editorial described a condition of mind which has been of late much in evidence in this

country, and particularly in high places: "A psychological affliction that clothes hopes in the raiment of fact and translates altruistic ambitions into accomplished ends."

Dr. Henry S. Pritchett, in a recent address, voiced a truth which we might all do well to keep continually in mind: "The world is full of devotion; but the devotion which thinks clearly, which has a true perspective, which can reckon with time, is rare."

Unquestionably our country has suffered much through the activities of those who, with honest intentions, have been conspicuously unqualified, or positively disqualified, to effect constructive reforms. If we confine our consideration to results alone, it is not improbable that the country has suffered as much from the ill-directed zeal of these honest but self-sufficient enthusiasts as from the cunningly directed activities of the reformers for personal profit. Those of the first class win the support of the credulous and uninformed through the very fact that they are credited with being personally honest and disinterested. In trying to differentiate between these two classes it is well to appreciate that there are those who, while personally honest, are mentally crooked.

Under our form of government it is necessarily difficult to preserve a just balance between those who in actual practice are governed and those who are elected or chosen in one way or another to govern. Here a great responsibility rests upon the specialists in political economy. And, I fear, it is true that if the account could be completely written up, debits and credits, we should find that many of these men have added heavily to the price we pay for our democracy. And is this not the natural result of the teachings and influence of men who attempt to qualify as leaders of their fellows by studying each others' books while neglecting that great educational agency which none can safely neglect,—the school of human experience? Thus we find that many of these inexperienced schoolmen are intellectually the inferiors of those they assume to instruct and lead.

The result of the activities of these enthusiasts, dishonest reformers and inexperienced schoolmen has been the enactment of a multiplicity of laws and the strained interpretation and en-

forcement of laws old and new; and this result not infrequently has evidenced a desire to punish rather than an unselfish purpose to develop better conditions. The multiplying of the laws, apart from the question of their content, is an evil to be controlled.

In an address delivered some months ago, Elihu Root condemned this national weakness. He said in part: "We make too many laws. Our national and state legislatures passed 62 014 statutes during the five years from 1909 to 1913 inclusive. During the same five years 65 379 decisions of the national and state courts of last resort were reported in 630 volumes. Of these laws, 2 013 were passed by the National Congress; and of these decisions, 1 061 were rendered by the Supreme Court of the United States. Many of these statutes are drawn inartistically, carelessly, ignorantly. Their terms are so vague, uncertain, doubtful, that they breed litigation inevitably."

Here is a warning delivered by a man who speaks from a wide and special experience; a warning coming from such a source we cannot afford to disregard.

This deplorable condition, while rendering general and consistent enforcement of law difficult when not impossible, does offer a weapon to the blackmailers, a weapon which they are prompt to use. Then the amateur reformer again becomes active, and, to cure the non-enforcement or misapplication of these too many laws, agitates enthusiastically for the enactment of still more laws.

Here there is need to control honest but reckless enthusiasts as well as the reformers for personal profit. Let us be true with ourselves and face the fact that too many representatives of both of these two classes can be found in our national and state legislatures.

Examples of the insincerity of much of the reform activities of our legislative bodies can be found, most unfortunately, in the records of many of the special legislative investigations conducted during recent years. Naturally, these investigations sometimes have brought to light transactions which deserved exposure. But this result, which can and should be made to work for good, is too often accompanied by processes and results which are mean and grossly unjust. Frequently these

investigations are so conducted as to prevent the development of a complete record. Would it be unfair to say that rarely in such investigations is there a well-sustained purpose to place on the record the truth, the whole truth, and nothing but the truth? A witness is required to take an oath to so testify, but the chairman prevents him from so testifying. And is it not easy to see why these investigations are so frequently a shame to us who permit such conditions to exist? They are frequently set on foot, not to learn the truth wherever that may lead, but to develop a record which can be used to influence voters in favor of the political party responsible for the investigation. Thus those who are earnestly opposed to the corrupt practices sometimes exposed are prevented from giving full support to those exposing these practices because they question the fairness of the investigation. No doubt the question has occurred to many of us, What if the investigators were themselves impartially and effectively investigated?

In many cases, because they are not permitted to tell their complete story, grave injustice is done to many who are required to testify. Witnesses are halted as soon as the point aimed at by the chairman of the committee has been gained. Opinions and statements of fact are taken out of their context. A man who will so conduct an investigation ("the act or process of searching minutely for truth, facts or principles") is far lower in character than many a poor devil imprisoned for some petty crime. And the fault rests with us, for we fail to regard these men as dishonored, and we take them by the hand in real or professed friendship.

A recent example of investigations which do not investigate is the Thompson "investigation" in New York. I quote from a letter recently written by Controller Prendergast of New York City to Chairman Thompson of the committee: "In the statements I have heretofore deemed it necessary to make regarding the subway controversy, I have charged that you have been conducting the investigation in such a way as to distort facts and evade real issues. I have before me, in a statement attributed to you, in a morning paper, absolute confirmation of the opinions I have expressed regarding your work. . . . This

statement on your part is a cowardly attempt to give a dishonest twist to the situation." A number of my friends who have been present at the hearings, having no direct interest in the matters at issue, have given me accounts of the methods pursued by Chairman Thompson which justify Mr. Prendergast's vigorous protests.

Another recent example stands out by itself from the many cases which call for the reprobation of all decent men, — the investigation of the Federal Industrial Commission conducted by Chairman Walsh. In at least two cities, *before the opening of the hearings*, this man, in public addresses, showed that his opinions were radical in the extreme and were already firmly fixed. In answer to criticisms of his course, he was reported as saying that he was not of a judicial turn of mind and he proposed to conduct his "*investigations*" on the basis of the opinions he already held. Think of such a man being appointed to conduct a vitally important nation-wide investigation, and think of the humiliation of those who were willing to continue to serve on the commission under such unworthy leadership and to accept their share of the responsibility for his demagoguery! Think of the responsibility resting upon those who appoint such men to positions of such tremendous influence for good or ill to the country at large! Such a man as this chairman is incapable of understanding that the maximum of progress, both as to rate and permanency, is secured only by the retention of all elements which have successfully met the test of years. True progress means conservation of all the good, and elimination of the bad only. Our present-day reformers are too ready to pronounce as bad, on the score of age alone, all that has so met the test of years.

Now it may be thought that I am charging too much that is inefficient or evil against democracy. I am endeavoring only to point out the evils to be avoided, and also to guard against the belief that we can enjoy all of the advantages of democracy while escaping its disadvantages.

We must also keep in mind the difference between true and false democracy. Nicholas Murray Butler, president of Columbia University, makes this differentiation clear: "Jealousy of power honestly gained and justly exercised, envy of attainment

or of possession, are characteristics of the mob, not of the people; of a democracy which is false, not of a democracy which is true. False democracy shouts, Every man down to the level of the average. True democracy cries, All men up to the heights of their fullest capacity for service and achievement. The two sides are everlastingly at war. The future of this nation, as the future of the world, is bound up with the hope of a true democracy that builds itself on liberty."

Here is our problem: To strive continually for the development and maintenance of a true democracy, and so for our liberty pay as small a price in inefficiency and injustice as conditions permit.

Now how do these deplorable conditions, which I am sure are not overstated, affect the regulation of public utilities by the public service commissions, Federal and State? Here certainly we have had to pay the price for our democracy in loss of efficiency and economy and frequent exhibitions of injustice.

As quasi-public institutions, and under the conditions which control, the public utilities are natural monopolies. As such they should be regulated as far as is necessary to secure compliance with the law; and this being granted, they should be protected in their rights, including that of monopoly. The fact is, however, that the advent of commission regulation has not eliminated competitive raids, with the result that many of the public utilities are laboring under the burden of over-capitalization for which they were not primarily responsible. Many of these raids were initiated in our legislative halls.

As it appears to me, there are two fundamental conditions which should limit the regulation of our public utilities.

First: The initiative of the public service corporations should not be destroyed.

Second: The public service commissions should not be permitted to exercise the three functions of government, — the legislative, the executive, and the judicial.

As to the first we may well keep in mind the teachings of Thomas Jefferson: "Agriculture, manufactures, commerce and navigation, the four pillars of our prosperity, are most thriving when left free to individual enterprise."

As to the second condition, we find that the Democratic platform, constructed at Baltimore in 1912, contains this plank, which simply reaffirms a fundamental principle of our government: "We believe in the preservation and maintenance in their full strength and integrity of the three coördinated branches of the Federal Government, the Executive, the Legislative and the Judicial, each keeping within its own bounds and not encroaching upon the just powers of either of the others."

In the face of this recent restatement of a vital principle by the party now in power, it is discouragingly significant to recognize, as I think we can, that this principle never has been so constantly violated as during the last three years.

As far as I have been able to observe, and I have been keen to watch the trend of events in this connection, the protests made against this violation of a bedrock principle of our government are rare. I cannot see how our form of government can persist in its integrity if this violation of principle is to be permitted to persist. We must choose between the two.

Under commission control, over-regulation and unnecessary interference with individual enterprise has been gaining headway year by year. The tendency to allow this one authority to exercise the three functions of government has been year by year more in evidence. The regulation of business in many cases has developed or, more correctly, degenerated into persecution; and this also applies to business other than that of the public utilities. Perhaps the burden of over-regulation has rested most heavily upon our railroads. The sooner the people as a whole come to understand that upon the prosperity and efficiency of our railroads depends in large measure their own prosperity, the better for all concerned. Sooner or later they will learn whose ox is being gored, but they may not be able to distinguish the aggressor.

The tendency of these commissions, Federal and State, is to get deeper and deeper into the details of management, to become more and more active in legislation and the framing of major and even minor rules, and to be more and more keen to sit as judges in trials of public service corporations.

The annual reports of the Interstate Commerce Commis-

sion are enlightening in this and other respects. I commend them to your study.

The last annual report, that of December 1, 1915, states as follows as to the period covered: "Except as otherwise noted, the period covered by this report extends from November 1, 1914, to October 31, 1915." We find that certain data are given for the calendar year, and that the fiscal year is from July 1 to June 30. This is somewhat confusing. The following data are for the year ended October 31, 1915.

Complaints entered on Informal Docket, 6 500, a decrease, as compared with preceding year, of 1 380.

Applications filed on Special Docket, 6 690, an increase of 1 176.

Complaints entered on Formal Docket, 964, a decrease of 190.

Cases decided.....	902
Cases dismissed.....	205

Total.....	1 107
an increase of 243.	

Hearings conducted, 1 543, in which 200 438 pages of testimony were taken, as compared with 1 607 hearings and 179 569 pages of testimony taken during the preceding year.

In this part of the report, this appears: "It might have been expected that as the years pass the decisions of the commission would result in a decrease in the volume of this work, but it has not so developed."

Suspension of Schedules Docket:

Cases instituted, 199, a decrease of 4.

Cases disposed of, 210, an increase of 51.

Special investigations of railroads and other interests:

<i>Concluded:</i> Ordered by Congress.....	4
At instance of Commission.....	6
<i>Still open:</i> Ordered by Congress.....	2
At instance of Commission.....	25

There were filed with the commission, tariff publications containing changes in rates, fares, classifications or charges, 149 449, an increase of 418 as compared with the eleven months ended October 31, 1914; an increase of 40 683 as compared

with the year ended November 30, 1912; but a decrease of 78 954 as compared with the year ended November 30, 1908, the first year recorded.

For the fiscal years ended June 30, the expenditures were:

	1912-1913.	1914-1915.
Salaries, Commissioners and Secretary.....	\$73 111.10	\$74 277.78
" All other authorized expenditures ".....	846 003.23	998 833.07
Examination of accounts.....	297 517.93	296 978.31
Locomotive boiler inspection.....	198 029.15	208 393.70
Safety appliance, block signal, and hours of service	135 376.47	223 517.58
Valuation.....	10 366.33	2 131 924.74
Totals.....	\$1 560 404.21	\$3,933 925.18

Increase in two years, \$2 373 520.97, of which \$2 121 558.41 is on account of valuations.

This record shows a vast amount of work performed and very wide powers exercised, and yet, in this report, as in previous reports, we find the commission asking Congress for *more work and more power*. And this request is now made to the representatives of the political party of which Thomas Jefferson is spoken of with pride as its "most distinguished apostle."

No seven men could be found who would be capable of doing this great work effectively, efficiently, thoroughly and fairly. Judge Prouty, then chairman of the commission, voiced this opinion in an address delivered in 1907. If true in 1907, it is certainly true to-day.

If these faulty laws, laws giving far too great powers to these commissions, were always or even generally administered with full knowledge and understanding of the facts and conditions, with wise discretion, and with proper restraint; if the commissions concerned themselves only or more particularly with the larger questions of principle and policy, the danger to our vested interests and the country's prosperity would be greatly lessened. But the fact is the commissions more and more concern themselves with and exercise their authority with respect to the details of design, construction, production, management, administration and financial policy. *Thus they exercise*

the authority while avoiding responsibility for final results — a most inefficient and dangerous system.

While the Federal and State commissions have instituted some much-needed reforms, they have, on the other hand, done much which has been injurious, unnecessarily injurious, to the industrial and commercial life of the nation. If a fair analysis were made of the complete record of their activities, I can hardly believe that the balance would be found in favor of the commissions.

To the railroads of the United States, and so to the pioneers in the development of these railroads, should be given the credit in full measure for their great part in the material development of this country. Undoubtedly the full account would show debits also, but there would be a heavy credit balance. And yet the railroads have been so hampered and hindered by the Interstate Commerce Commission, the state commissions, *and those using the commissions as their tools*, that the railroad situation has been causing deep concern to railroad officials and bankers, and finally is beginning, fortunately, to cause alarm to the innocent small investors in railroad securities.

The report of the Securities Commission, so strong in its membership and so wisely presided over by President Hadley, of Yale, should have been taken more seriously by the commissions and the authorities in Washington. The report of this commission, a report exceptional in its conclusiveness, disclosed conditions demanding prompt and effective remedies. And yet for three years after the rendering of this report, the conditions under which the Interstate Commerce Commission obliged the railroads to operate were even more difficult and oppressive. Recently there has been a little more indication of open-mindedness and courage to act on the facts.

Why is it that the railroads of the United States are so oppressed? Is it because by comparison with other countries our railroads are over-capitalized, exact excessive charges for freight and passenger traffic, afford inadequate facilities and accommodations to its patrons, or underpay its employees? These questions are all explicitly negatived by the facts.

The average capitalization per mile of our railroads is

less than one fourth that of England, a little less than one half that of France, and a little more than one half that of Germany. It costs about one third as much to move a ton of freight a mile in the United States as it does in England, and about one half as much as it does in France or Germany. Passenger fares, first-class, are much lower than in either of these countries. The accommodations and facilities offered by our railroads have set the pace for the railroads of Europe.

The average daily wage paid railroad employees in this country is about 65% higher than the wages paid by English railroads, about 150% higher than paid by the French railroads, and about 175% higher than paid by the German railroads.

Do our railroads fail to do their share toward the support of the government?

In 1902 the railroads paid in taxes an aggregate of over \$54 000 000, amounting to $8\frac{1}{3}\%$ of their income. Ten years later they were paying over \$140 000 000 in taxes, amounting to nearly $16\frac{3}{4}\%$ of their income, an increase in the period of almost 160%. This increase of \$86 000 000 would pay 5% on \$1 720 000 000.

In the rate case argued in Washington about two years ago, it was shown that the average return on railroad capital was less than 4%, while at that time railroads of established credit were paying as high as 7% on the short-time renewals. It is true that this was a time of depression and lack of confidence, but these were conditions due in large measure if not entirely to over-regulation and general interference on the part of government. Conditions have somewhat improved, but this improvement is largely accidental and cannot be credited to changes in government policies or procedure.

Another direction in which the railroads have been unfairly treated is in the carrying of the mails, and particularly in connection with the parcels post. Here the railroads were called upon to render a great additional service without adequate additional compensation. Ex-President Taft, while endorsing this addition to the government's activities, has this to say: "There is one thing connected with the parcels post that ought not to meet the approval of anybody, and that is that we have

not given the railroads appropriate compensation for the additional burden that they have to carry by reason of the parcels post," — and then he goes on to say with characteristic optimism, an optimism which has not been justified by the facts, "but after a time Congress will see its duty and make reparation in this regard, I hope." This was said over two years ago, and the railroads are still looking and working openly and intelligently to hasten the time of reparation.

Even President Wilson, in answer to an appeal of the railroad managers, in September, 1913, said:

"You ask me to call the attention of the country to the imperative need that railway credits be sustained and the railroads helped in every possible way, whether by private coöperative effort or by the action, wherever feasible, of governmental agencies, and I am glad to do so, because I think the need very real.

"The interest of the producer, the shipper, the merchant, the investor, the financier and the whole public in the proper maintenance and complete efficiency of the railways is too manifest. They are indispensable to our whole economic life, and railway securities are at the very heart of most investments, large and small, public and private, by individuals and by institutions.

"I am confident that there will be active and earnest co-operation in this matter, perhaps the one common interest in our industrial life. . . .

"But the emergency is, in fact, extraordinary, and where there is a manifest common interest we ought all of us to speak out in its behalf, and I am glad to join you in calling attention to it. This is a time for all to stand together in united effort to comprehend every interest and to serve and sustain it in every legitimate way."

Since writing the above, President Wilson, in a letter to the majority leader of the House of Representatives, has this to say of the proposed investigation with respect to amending the acts regulating the common carriers of the United States:

"The railways of the country are becoming more and more the key to its successful industry, and it seems to me of capital importance that we should lay a new groundwork of actual facts for the future necessary regulations.

"I know that we all want to be absolutely fair to the rail-

roads, and it seems to me that the proposed investigation is the first step toward the fulfillment of that desire."

The pity of it is that the views of the President himself at the time he assumed his high office were in great need of readjustment as to the railroads and all other departments of the country's industries. Furthermore, I can find no sufficient basis for his statement of belief, "I know that we all want to be absolutely fair to the railroads." Was it fair to the industries of the country to appoint Walsh as chairman of the Federal Industrial Commission?

Apparently the "common interest" is not yet "manifest" to those who have the power to regulate and control, nor to those who have the power to change the laws through which these interests are regulated and controlled. In the case of some of those who have the power, the "voice of the people" has not yet indicated to them the need of a change. If that voice thus is heard, those in power will recognize promptly that they have a call to change their views.

If this "common interest" is to be recognized by those in power, the financial condition of the railroads of the country might well be kept in mind. Last fall there was made a study of certain railroad statistics. The result was, to me, startling. Since then, these conditions have somewhat changed for the better, and particularly as to certain properties; but the lesson is still to be heeded.

In 1906, the quotation for railroad stocks averaged about 138. Last fall this average had fallen 48 points. The net revenue had increased about \$10 000 000 over the year before, the reduction of expenses showing a reduction of \$140 000 000 to \$130 000 000. Here we may assume that this reduction, in part at least, is represented by smaller expenditures for maintenance, a dangerous way to save money. One eighth of the railway mileage was in the hands of receivers. In more than one case, stockholders had been obliged to face either an assessment of \$50 a share or a total loss of their investment. But this loss did not fall on the stockholders alone, for the average number of railway employees had fallen *in one year* from 1 815 239 to 1 695 483.

We must not forget that the prosperity of the country depends upon the ability of the railways to make extensions and betterments. Here comes in an element which the government and its commissions cannot control—the will of the investors; these people who lend the money to the railroads have the final word. If they are not protected in their property rights in connection with railroad investments, they will not risk more money along the same lines. Of late the total new mileage has been negligible as compared with years past, when the railroads were not so over-regulated. This alone is a great national question.

I have shown that the annual cost of operating the Interstate Commerce Commission increased, from 1913 to 1915, \$2 373 520, and that of this increase \$2 121 558 was chargeable to the valuation of railroad properties. In the commission's report of December 1, 1915, we are told that there are in the United States about 250 000 miles of railroad, and that with the present force the work on about 45 000 to 50 000 miles a year can be completed. By January 1 this year it was expected that 50 000 miles would be completed, leaving 200 000 miles, the work for four more years. In commenting on this work, the report says: "It seems to be universally conceded that in addition to the amounts obtained by the application of unit prices to the quantities shown upon the inventory, certain additions, commonly known as overhead charges, must be made. These items are of significance, and no opinion should be expressed upon them without the fullest possible information. Here, again, an examination of the accounts of carriers for the purpose of ascertaining what the amounts have actually amounted to in the past is of first importance, nor would it be safe to accept the result obtained from one or even from several carriers."

Again: "Experience indicated that it will be possible to obtain with reasonable certainty those facts called for with respect to the corporate and financial history of the carrier, but that it will not be possible in all instances to give the original cost 'in detail as to each piece of property,' as called for by the act."

It is encouraging to find that the commission has discovered that the valuation project has its serious difficulties and calls for the exercise of a high order of judgment to develop the truth. I venture to suggest that in very few cases can the whole truth be developed as to the "overhead charges" and the financial history by an examination of the accounts. I fear that too much reliance is being placed upon inventories. Those of us who have had to do with the extensions of existing properties, or the construction of plants in which, for instance, street obstructions have had to be dealt with, can understand far better than these commissioners that vast sums are necessarily and legitimately spent on construction which never can be represented adequately by the bare bones of an inventory.

There are many engineers who might profitably give more attention to the subject of overhead charges, including such items as preliminary expenses, legal and other organization expenses, engineering, superintendence, contractor's expense, interest and taxes during construction, liability and other insurance, omissions and contingencies, etc.; and it might be well, even if the engineer does not assume the responsibility for the expense of financing, for him to remember that this is frequently a heavy item of cost. In other words, if the engineer's estimate is not inclusive and final, he should recognize that fact and place it on the record. Engineers have been responsible for much misapprehension because of their failures in this respect.

But we have only seen so far what it is costing the government to do this unnecessary work, the *ultimate purpose of which has not been decided even by the commission.*

It was originally estimated that it would cost the railroads of the United States to complete their work on the valuations \$6 000 000. It is now seen that this is far below the probable cost, and an estimate recently made is \$50 000 000. I believe that the direct and indirect cost will exceed this last amount.

The railroads, through their joint committees, are loyally coöperating with the commission in this work, but naturally they would be encouraged if they knew how these data, accumulated at such vast cost and inconvenience, are to be made to serve a useful purpose. I believe it can safely be asserted that the

commission is not as yet able to inform the railroads, and this for the reason that they, themselves, do not know.

Since writing this address, it has been my privilege to read a paper entitled, "The Federal Valuation of Railroads," by Morrell W. Gaines, of Brown Bros. & Company, reprinted from the *Yale Review*, April, 1916. I quote the two first paragraphs of Mr. Gaines' admirable paper, in the hope that many of those present may thus be induced to read it in its entirety:

"Railroad control by governmental commissions is properly a means and not an end. It glitters with technique and is refulgent of policies. But it tends to become its own object and to spend itself in a futile perfecting of administrative machinery. This has become more plainly evident since the war, by its vast consumption of capital, has made possible the goal of an ultimate re-financing, through which the stocks and bonds of the railroad companies should be transferred to the shoulders of the government. Of the mechanism that the commissions have conceived, the valuation of the railroads by the Interstate Commerce Commission is the most recent and most gigantic enlargement — the most searching in attack on the joints of the armor of private ownership. Viewed critically, it is but an uninspired assembling of barren facts, crude in its disregard both of practical results and of plain principles of ethics. Nevertheless, it is an approaching reality and will have consequences that must be reckoned with.

"Private ownership of railroads has become public investment in their securities. There are 622 000 stockholders. Directly and indirectly, there are some tens of millions of bondholders. The 11 000 000 deposit accounts in savings banks and the 40 000 000 life insurance policies derive both income and safety from railroad investment. The nation itself, in its individual capacity, already owns the outstanding sixteen billion dollars par of railroad securities. The owners and creditors of the railroads are not, therefore, a group or class; they are the people of the United States."

There are many items in addition to overhead charges on which the commission and the railroads will find it difficult to agree. One of these is so-called depreciation — the estimated cost of the renewals of plant to be made in regular course. Unless the annual charges for plant maintenance are so distributed over a wide area and for plant units of such varying age as to make the annual expenditures fairly near the annual average

total accrued cost of renewals, a reserve should be set up to cover this accrued liability. This reserve, which is intended, or should be intended, only to spread the cost of renewals uniformly over the years of service, does not represent real depreciation of plant. The use of the term "depreciation" in this connection is misleading. Under this theory the plant is still working effectively, efficiently and economically; otherwise it should sooner be renewed or replaced than is indicated in the estimate of expected life. The plant is guaranteed by the owning and operating company and is performing full service. This liability for subsequent renewals, which is so erroneously called "depreciation," is not the reduction in worth or value as viewed by a possible purchaser, but it is the accrued liability of the owner for the renewal of all parts as these parts become uneconomical, inefficient or inadequate.

As long as a public service property does not change hands, the corporation is obliged to make all necessary renewals; and if the property does change hands, the new owner has to assume this obligation. This is not a case where the capital in plant is to be amortized, but it is the case of a plant continued indefinitely in operation to meet the demands of the public.

To deduct from the value of plant on account of the accruing or accrued cost of renewals, if that deduction is enforced as influencing the rates for service or in any other way, *the plant in the meantime being maintained thoroughly*, means, necessarily, confiscation.

Thus far I have referred only to the Interstate Commerce Commission in connection with the railroads. But the railroads have the state commissions also to deal with. And here, not infrequently, they are called upon to obey orders from one commission which conflict with orders from another commission. Just by way of a suggestion, let me quote from an address by Alfred P. Thom before the State Bar Association of Tennessee:

"Three states have passed laws making it illegal for a carrier having repair shops in the state to send any of its equipment, which it is possible to repair there, out of the state for repairs in another state; fifteen states have attempted to secure preferred treatment of their state traffic, either by heavy penalties for de-

lays or by prescribing a minimum movement of freight cars, some of them requiring a minimum movement of fifty miles per day, whereas the average movement for the United States is not more than twenty-six miles per day,—one of these states imposing a fine of ten dollars per hour for the forbidden delay; twenty states have hours-of-service laws, varying from ten to sixteen hours; twenty states have full-crew laws; twenty-eight states have headlight laws, with varying requirements as to the character of the lights, and fourteen states have safety-appliance acts. Sixteen states have enacted statutes, each asserting for itself the individual right to control the issue of stocks and bonds of interstate carriers.

“It is manifest, that if such issue is to be regulated by the individual states, every state is at the mercy of the others. A bond, to be available in the market, must, as a rule—especially now when most bonds are necessarily junior liens—be secured upon the whole railroad line; and this crosses many states. One of the states, therefore, if it possesses the power to regulate the issue of securities of an interstate carrier, may defeat a financial plan approved by all the other states and necessary to the carrier’s transportation efficiency. . . .

“In other words, the greediest, the most selfish and the most unreasonable state thus secures by its own laws a preference for its own commerce over the commerce of its sister states and over interstate commerce itself.”

I attach as an appendix to this paper a letter from Mr. Stuyvesant Fish, published in the *New York Sun* of March 23, 1916, which is significant and enlightening in connection with this multiplication of agencies of regulations and the necessary evils thus developed.

Referring now to the state commissions, for I have had little personal experience with the Interstate Commerce Commission, it is particularly unfortunate that the hearings are so often conducted in a manner to bring discredit on the system. Even if there were no other reason for criticism, this would be a sufficient condemnation.

Frequently the presiding commissioner examines witnesses in a way to indicate partisanship and bias. Witnesses are so examined as to cloud and confuse rather than to clarify the record. The commissioner presiding should so examine witnesses as to make clear that which has been left obscure. Espe-

cially in the case of stupid or timid witnesses, he should consider it a privilege to develop the truth, the whole truth and nothing but the truth. While these incompetent witnesses should be assisted, the tricky witness should be relentlessly cross-examined.

I have listened to commissioners examining most sympathetically witnesses who were testifying for the complainants and against the public service corporation, and then examining witnesses for the corporation in a manner diametrically opposite. I could give instances of such unfairness and arbitrary power which the uninformed would find it hard to believe. I was concerned in a case where the presiding commissioner stated in his opinion that on a certain most important feature no direct evidence had been offered, whereas the evidence given was far more complete than in any other case within my knowledge. In fact, the evidence included the record, made up from the evidence of four witnesses, of a physical examination extending over days and carried through in great detail, twelve persons participating, representing the city, the commission and the public service corporation. In this same opinion the chairman laid the burden for a change in the keeping of the accounts upon the corporation, and imputed wrong motives in that connection, whereas the change had been made by the commission against the repeated protests of the company's president. Also in the same opinion, this chairman ascribed to a witness for the company evidence given in a previous case by a witness for the city who had, on cross-examination, been completely discredited. He then proceeded to compare this testimony with testimony on the same subject by a witness for the company in the present case, and, having shown the wide variations, proceeded to express the opinion that the testimony was valueless and that all engineers' testimony had to be received with great caution if not thrown out altogether.

I was concerned in a case where an expert for the city was allowed to testify with respect to many cities in the United States, Canada and Europe, but when the corporation's witness went on the stand to refute the testimony, he was at once confined to testifying with respect to the city directly concerned. In this case the chairman of the commission (all members of the

commission were sitting) refused to strike out the testimony of the city's expert with respect to the many other cities the complainant's witness had covered in his testimony, saying that he had changed his mind since he had permitted the city's witness such latitude, but he would keep the testimony on the record, as it might prove to be helpful. Fortunately such rank abuse of authority as this cannot pass a decent court on appeal. The trouble here is that many cases which should be carried to the courts are not appealed for reasons of policy, timidity or general lack of backbone. By experience, I am convinced that the corporations have suffered material loss and loss of prestige by this cowardly course. Unless the corporations fight for their just due, they are charged with being found in the wrong. They should be very sure they are right, and then fight to the limit.

While, of course, I have been concerned in cases before these commissions where the hearings were conducted fairly and decently, I am obliged to say that these cases have not, in my personal experience, been in the majority.

While the system of regulation needs to be reformed for the reason that it is fundamentally in conflict with our form of government, one improvement can be made as to the operation of the system. I have for years been making this suggestion. Now that it has come to pass that Judge Prouty and Commissioner Daniels of the Interstate Commerce Commission have made the same suggestion, we may hope that this opportunity for improvement may more often be accepted.

I believe that many of the minor troubles and the injustices could be eliminated from commission control if thoroughly qualified engineers were put on the boards. Many, almost all, of the questions which come before our commissions require for their solution the highest engineering training and experience. I hold, therefore, that every commission should have at least one engineer as a member. I do not for a moment contend that a man is qualified for this tremendously responsible and important office simply by reason of his being an engineer, any more than I believe that a man is qualified to be a competent and upright judge because he has been admitted to the bar. An engineer to be qualified for this position of grave responsibility

should be a man of high character, of sound training in theory and practice, and of wide experience in design, construction and administration. In general, all of our public service commissioners should be broadly trained, broad-minded, fair and competent as investigators (an unusual qualification); and in each commission there should be men fully qualified in the theory and practice of the professions of engineering, law, business, finance and accountancy.

The question then is, How shall we get enough of such men in view of the small inducements offered and the political pressure to which they are submitted? I confess I am unable to suggest a solution of this momentous problem.

I come back now to the proposition that in a democracy we must be prepared to pay a price for the liberties enjoyed under that form of government, but it should be our constant endeavor to reduce the price and so maintain it at the lowest possible figure. To this end we should keep in mind the difference between a false democracy and a true democracy. And here I venture to repeat President Butler's statement of the difference:

"Jealousy of power honestly gained and justly exercised, envy of attainments or possession, are characteristics of the mob, not of the people; of a democracy which is false, not of a democracy which is true. False democracy shouts, Every man down to the level of the average. True democracy cries, All men up to the heights of their fullest capacity for service and achievement. The two sides are everlastingly at war. The future of this nation, as the future of the world, is bound up with the hope of a true democracy that builds itself on liberty."

Thomas Jefferson, the third President of the United States, is credited with being the "most conspicuous apostle of democracy in America." I venture to repeat his warning also: "Agriculture, manufactures, commerce and navigation, the four pillars of our prosperity, are most thriving when left free to individual enterprise."

But in a government "of the people, by the people and for the people" we can do no less than expect that there shall be many suggestions looking to change in the details of government, and naturally the most vociferous voices will be heard and they

will be those of the enthusiasts, probably uninformed, or misinformed, or both, and those of the demagogue and reformer who looks for the opportunity for personal advantage or profit in the turmoil of change. We are constantly reminded that the "Voice of the People" should control. It is not the *voice* of the people as represented by those most ready to voice their opinions, but the sober second thoughts of the informed people which should guide us in all propositions looking to change in law and government. And here it is well for us to bear in mind that those who appreciate their responsibility the most are those who think first and speak last. Unfortunately the politicians with their ears to the ground hear and heed the vociferous voice, for they recognize that is the voice heard at election time.

When we are troubled with the activities of the selfish or vicious reformer, we are reminded of Lavater's dictum: "He who reforms himself does most to reform the public."

And when we are troubled with the activities of the uninformed or misinformed enthusiasts, we do well to keep in mind two quotations which help us to understand the condition of mind of these perhaps honest people, and which I venture to repeat. From the *New York Sun*: "A psychological affliction that clothes hopes in the raiment of fact and translates altruistic ambitions into accomplished ends." And from Dr. Henry S. Pritchett: "The world is full of devotion; but the devotion which thinks clearly, which has a true perspective, which can reckon with time, is rare."

True progress, true reform, is evolutionary, not revolutionary. Our reform, and particularly of late years, has been decidedly revolutionary, and so the price we pay for our democracy in the form of inefficiency and uneven application of law is increased rather than decreased. The people as a whole, through their representatives, should direct only as to principles and larger policies; the individuals should be left free to work out their own salvation with respect to the things less essential. And this principle should again be enforced in differentiating between the questions which affect the nation as a whole and the things which affect separate communities. While there should be a firm and binding national policy, simple and

uninvolved as is possible, there should be beyond that the greatest possible freedom as to home rule with respect to the separate communities.

Those of us who have had the opportunities to compare the fruits of individual enterprise with those of government ownership and management — and we have all had such opportunities, though we may not have intelligently and honestly availed ourselves of these opportunities — must acknowledge that a privately owned and conducted enterprise could not live if it had to carry the burdens of political favoritism and interference which go with government enterprises. And this is what all of our commercial and industrial enterprises are coming to unless the voters do some hard thinking for themselves and learn to despise the empty oratory of the mere vote seeker.

The fact is not sufficiently kept in mind even by the engineers themselves that engineering in one way or another permeates nearly every activity of our daily life.

Therefore, the engineers, by their book and laboratory education and their subsequent education in the school of experience, should be peculiarly qualified to analyze the questions presented to the public, and particularly those questions which are presented under a cloud of inconsequential rhetoric.

All this means that a peculiar responsibility rests upon the members of the engineering profession with respect to the duties of citizenship. No longer should we permit the lawyers and economists to make our laws and say how, when, and where they are to be enforced.

APPENDIX.

RAILROAD REGULATION.*

MR. STUYVESANT FISH URGES FULL EXERCISE OF CONGRESSIONAL POWERS.

TO THE EDITOR OF THE SUN:

Sir, — The editorial article of March 5 on "Federal Charters for Railroads," the letter by "Civitas" therein referred to, his later letter published March 14 and the one signed "Lex" in *The Sun* of March 16, all favor the enactment by Congress of laws for the incorporation of railroads.

The Sun and its correspondents are right in believing that neither the

* From the New York *Sun*, March 23, 1916.

railroads nor the people served by them can longer endure the economic waste arising from the regulation of our commercial highways, railroads, by the Federal Government, by some forty-odd state commissions and by municipalities.

But will the granting of Federal charters bring the regulation of railroads under one single control? Many strong railroad corporations enjoy invaluable rights under their state charters, such as perpetual succession, exemptions from or peculiar provisions in respect to taxation, powers to cross and divert waterways and highways, to condemn needed lands and to make by-laws for the conduct of their business. Such contractual rights directors cannot, in justice to their stockholders, relinquish. However attractive Federal charters may seem to bankrupt railroads in process of reorganization and to the promoters of new ones, it is not to be expected that the strong companies will avail of them. Especially is this true of those which, by paying dividends for many years, have established in their present corporate names a credit known all over the world. The enactment of Federal laws for the incorporation of railroads will therefore tend to complicate further the situation by creating a new class of corporations, without getting wholly rid of the two existing classes created by individual states and by groups of states respectively.

The Constitution of the United States as adopted in 1787 and now in force gives to Congress power "to regulate commerce with foreign nations, and among the several states, and with the Indian tribes."

The powers thus granted in respect to commerce with foreign nations and with the Indian tribes were availed of at once. The advent of steamboats was at an early day followed by legislation for the regulation of all of them, everywhere.

* Congress, having in 1823 enacted "that all waters on which steamboats regularly pass from port to port shall be considered and established as post roads" (Statutes at Large, III, page 767, being Section 3 of Chapter 33), in 1838 further enacted "that each and every railroad within the limits of the United States which now is or hereafter may be made and completed, shall be a post route" (Statutes at Large, V, page 283, being Section 2 of Chapter 172). There were then few if any railroads crossing state boundaries. In the whole country there were but 1 843 miles of railroad.

At that time, July 7, 1838, President Van Buren also approved another act for the better security of passengers on steamboats. (Statutes at Large, V, page 304, being Chapter 191.) This required "all owners of steamboats," without exception, to take out a new license thereunder, and made it unlawful to transport goods or passengers without such license. That act called for the periodic inspection of boilers, machinery and hulls; required the employment of a competent number of skilled engineers; that the safety valve shall be opened whenever a vessel is stopped; that every steamboat running between sunset and sunrise shall carry signal lights visible to other boats; that every person employed on board any steamboat by whose misconduct, negligence or inattention to duty the life of any person on board may be destroyed shall

be guilty of manslaughter and on conviction sentenced to confinement at hard labor for not more than ten years; that in all suits against owners of steamboats for injuries arising to person or property from the bursting of the boiler, or the collapse of a flue, or other injurious escape of steam, the fact of such bursting, collapse or injurious escape of steam shall be taken as full prima facie evidence, sufficient to charge the defendant, or those in his employ, with negligence.

In 1852 an exception was made as to steam ferry boats and canal boats. But at present, and since at least 1871, all vessels and boats propelled in whole or in part by steam, navigating any waters "which are common highways of commerce," are under Federal regulation, with the single exception of canal boats. (Revised Statutes, Title III, Chapter I, Sections 4399, 4400.)

Although most of our great railroad systems, substantially as they exist to-day, had been organized under state laws long before 1887, it was not until then that Congress began to legislate concerning their regulation, and in so doing it has as yet availed of but a part of its constitutional powers over them. The initial paragraph of that which has come to be called the interstate commerce law, but is entitled "An Act to regulate commerce," approved February 4, 1887, limits the application of the law, in so far as it relates to "commerce among the several states," to common carriers engaged in transportation "from one state or territory of the United States, or the District of Columbia, to any other state or territory of the United States, or the District of Columbia," and ends as follows:

"Provided, however, that the provisions of this act shall not apply to the transportation of passengers or property, or to the receiving, delivering, storage or handling of property, wholly within one state, and not shipped to or from a foreign country from or to any state or territory as aforesaid."

Had that law been made to apply, without limit, to all carriers by rail engaged in "commerce among the several states," such commerce would long before this have been freed of conflicting Federal, State and municipal regulations.

The time has now come when Congress must either avail of its power to regulate commerce by rail in its entirety, that is, wherever such commerce exists and in respect to whatever it consists of, "among the several states," or confess failure and abandon the attempts thus far made to regulate only so much thereof as passes from one state to another. Neither the railroad corporations, nor the merchants engaged in commerce, nor the ultimate consumers, who finally pay the cost, can longer endure the uneconomic chaos in which the actions of forty-eight mutually jealous states have involved and are further involving such commerce.

As long ago as in the Mississippi Railroad Commission cases (*Stone v. Farmers Loan and Trust Co.*, et cetera, 116 U. S.), heard by the Supreme Court in 1885 and decided in January, 1886, the late James Fentress argued on behalf of the Illinois Central Railroad Company for the all-embracing nature of the power of Congress over commerce by railroad. I have been unable to find a copy of his brief, but well remember that among other things it showed

that the word "among" means "in the midst of," that it cannot be applied to two but only to larger numbers, while "between" must of necessity refer solely to two; and further that the use in the commerce clause of the words "the several" to qualify "states" absolutely precludes such a narrow meaning as that the power of Congress is limited to the regulation of commerce between two states or two groups of states. The cases last above referred to involved other issues, and the court did not see fit to rule on the particular point thus raised by Judge Fentress. The court did, however, say, "Nothing can be done by the Government of Mississippi which will operate as a burden on the interstate business of the company."

I am not unmindful of the fact that decisions of the Supreme Court have been cited to show that Congress has no power over railroads in respect to such of their business as has both origin and destination in the same state, but let me ask, How far have those citations become available to that end by reason of the non-action of Congress from the inception of railroads in 1830 down to 1887, and by its then exercising but a part of its power to regulate railroads? I have always believed and often publicly said that when Congress shall legislate in respect to railroads in the precise language of its constitutional power to regulate "commerce among the several states," without making any exception, the court will sustain the constitutionality of the act.

The evils under which our whole people suffer are commercial and national, and their removal calls for the exercise by Congress in respect to railroads of all its powers over commerce. Except in the matter of rates charged, Congress has for eighty years most minutely regulated all steam carriers by water. It is high time that it should regulate all carriers by rail, and do it everywhere, "among the several states."

STUYVESANT FISH.

NEW YORK, March 22.

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DISCUSSION OF POWER ESTIMATES FROM STREAM
FLOW AND RAINFALL DATA.

BY MESSRS. ALLEN HAZEN, CLEMENS HERSCHEL, E. F. CHANDLER,
C. H. PIERCE, E. S. GLINES, H. K. BARROWS AND
DANA M. WOOD.

MR. HAZEN* (*by letter*). — The writer is glad to see that the distinction between computations from monthly averages, from weekly averages and daily records is made. It might be made even more emphatic with advantage. Monthly averages are convenient. Sometimes the daily flows are not available, but where storage is not at hand to balance the irregularities of flow during each month, the error that may result in computations based upon monthly figures is quite large.

This is illustrated by Table I, which shows the percentages of time that flows of given sizes are apparently available for two streams; namely, the Manhan River and the Susquehanna River; first, on the basis of the daily records; second, on the basis of the monthly records.

The figures obtained from the daily records are substantially exact, and the differences show the errors reached in using the monthly figures. In all cases, the monthly figures give much higher results, and if a plant is built on the basis of computations based on them, the operating results will be disappointing.

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TABLE I.
ERROR MADE BY USING MONTHLY AVERAGE FIGURES.

Flow as Per Cent. of Mean Flow.	MANHAN.		SUSQUEHANNA.	
	Per Cent. of Time that Full Flow is Available.		Per Cent. of Time that Full Flow is Available.	
	Daily Records.	Monthly Records.	Daily Records.	Monthly Records.
0.3	65	69	75	81
0.5	48	63	56	64
0.7	37	51	44	53
1.0	27	37	31	40
1.5	17	23	20	24

The writer also wishes to suggest that, rather than take second-feet per square mile as a basis for the calculations, it will often facilitate comparisons to use instead as a basis the mean flow. In this case, all the rates that are discussed are referred to as percentages of the mean flow. This was done in Table I. The mean flow of a stream for a term of years is usually either known or is estimated as a starting point. The wheel capacities are then stated in terms of the mean annual flow. Comparisons between data for different streams arranged in this way indicate less variation between different streams than where second-feet per square mile is taken as a starting point.

To illustrate, Table 2 shows the characteristics of flow of three streams. The wheel capacity is shown as a percentage of the mean flow. There is next shown the percentage of the whole time when wheels can be operated at capacity without storage; that is to say, the percentage of the time when the flow of the stream is greater than the amount in the same line of the first column. There is next shown the summation of all the flows smaller than the assumed limit, the amounts of the summation being expressed as a percentage of the total annual flow; and finally there is shown the total flow that can be utilized, which is made up of the whole of the sum of the flows less than the limit, and the amount that can be utilized of the flows above the limit, which is practically the wheel capacity for that portion of the time for which the flow exceeds the limit. For example,

for the Connecticut River, with a wheel capacity equal to 60 per cent. of the mean flow, the flow is in excess of the limit for 50 per cent. of the time, and during this 50 per cent. of the time the total flow utilized would be 60 per cent. of 50 per cent. or 30 per cent. of the whole flow. During the 50 per cent. of the time when the flow is less than the limit, the whole amount of flow or 18 per cent. of the whole annual flow can be used, and, adding this to the 30 per cent., it is found that 48 per cent. of the total flow (as shown in the table) can be utilized with this amount of wheel capacity.

TABLE 2.

Wheel Capacity as Per Cent. of Mean Flow.	Per Cent. of Whole Time at Which Wheels can be Operated at Capacity.			Percentage of Total Flow during Days when Less than Full Capacity Flows.			Percentage of Total Flow that can be Utilized by Wheels.		
	C.	S.	M.	C.	S.	M.	C.	S.	M.
10	100	97	92	0	0.3	0.6	10	10	10
20	95	86	77	1	2	3	20	20	18
30	79	75	65	5	5	5	28	27	25
40	67	65	56	9	8	9	36	34	30
50	57	56	48	14	12	12	42	40	36
60	50	49	42	18	16	15	48	45	40
70	44	44	37	22	20	19	53	50	44
80	39	39	33	26	23	22	57	54	48
90	34	35	30	30	27	25	60	58	52
100	30	31	27	33	30	28	64	61	55
120	24	26	22	40	36	33	69	67	60
150	17	20	17	48	44	40	76	74	65
200	12	13	12	60	57	49	83	82	72
300	5	6	7	75	74	61	91	90	81

C=Connecticut River, Holyoke, Mass., 8 660 sq. mi., by ten-day periods for twenty years from 1880 to 1899. Clemens Herschel, Trans. Am. Soc. C. E., LVIII, 29.

S=Susquehanna River, Harrisburg, 23 885 sq. mi., daily records for twenty-two years, 1901-1912 inclusive; reports from the Penna. Water Supply Commission, Farley Gannett, engineer.

M=Manhan River, of Holyoke, Mass., Water Works, 13 sq. mi., daily records for fourteen years, 1897-1910 inclusive; weir gagings by James L. Tighe, city engineer.

This table also shows the amount of water that can be diverted by a canal or aqueduct of a given capacity.

The three streams shown in this table have very great differences in size, character of watershed, and amount and rate

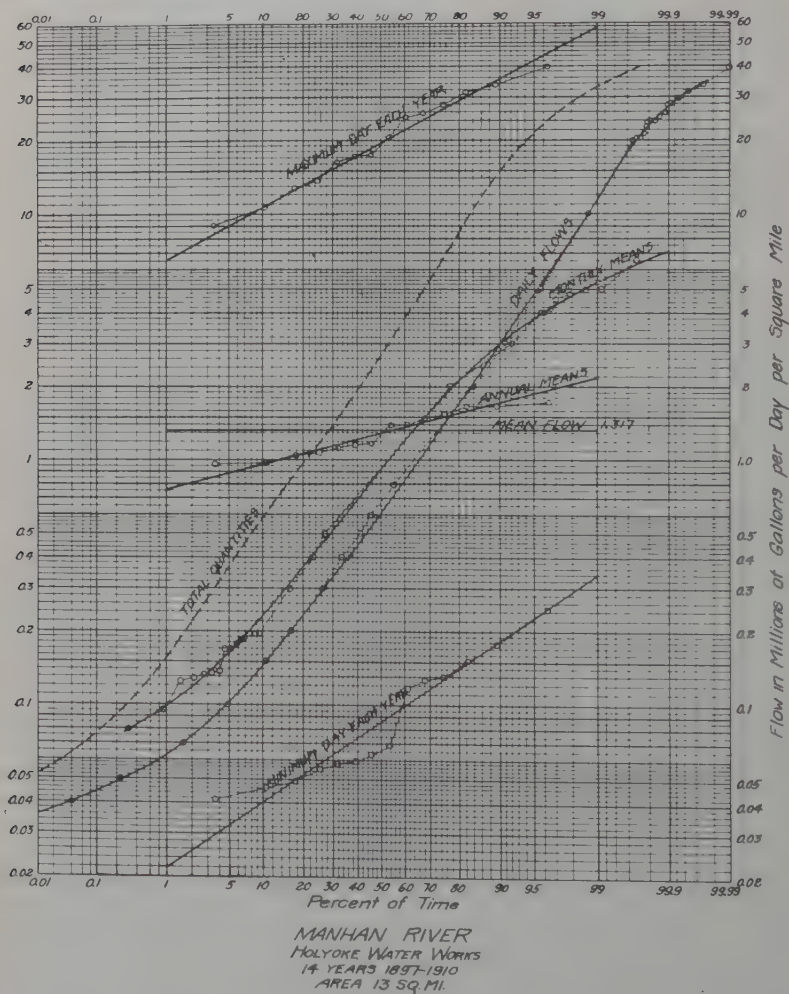


FIG. 1.

of run-off, but the figures reached by this method of comparison show only a moderate range and will serve as a basis for many estimates with a fair degree of probable accuracy.

These figures were obtained from the original records by arranging the figures in groups according to magnitude and plotting them on logarithmic probability paper, following the general methods used in the paper presented by the writer to the American Society of Civil Engineers, Vol. LXVIII, page 1539. One of the diagrams made, representing the flow characteristics of the Manhan River, and which shows not only the data used in this discussion but also the flood flows, the minimum flows and the annual means, is presented herewith. (Fig. I.)

RAINFALL RECORDS AND RUN-OFF.

MR. HERSCHEL* (*by letter*).—Some seventy years ago, about the time when the Croton and the Cochituate (the first New York and the first Boston) gravity water works were built, their engineers began to publish rainfall observations, and began to make the attempt to deduce from them for future prognostications annual and monthly yields of rainfall, or of river run-off, to use the modern term. And that sort of striving to compute the incomputable has continued down to the present day. The term "incomputable" has been used advisedly, because no direct relation between annual, monthly or any other period of rainfall and the run-off during the same period of time has ever yet been discovered, nor ever will be. It was soon seen that in some months more water ran off than fell, even in New England with only about 50 per cent. average annual net yield of rainfall, but varying between wide limits of annual percentage. In England, where the annual yield is some 75 per cent. of the rainfall, this excess of yield over the producing cause occurred in sixty-four months out of three hundred and twenty-four months observed, varying from six such months in one year to no such month in a year; or, in another case, in sixteen months out of eighty-four months of observation, varying from three months in a year to one such month in a year.† Such yield varies also according to the distribution of the rainfall throughout the year—whether in small rainfalls at short intervals, or

* Civil and Hydraulic Engineer, New York.

† Min. Proc. Inst. C. E., 1912-1913, Pt. 4, p. 94.

whether the same total amount falls in one or a few showers. So that years of the same rainfall yield very different run-offs; and less total rainfall will often yield a greater run-off; and vice versa.

Then, again, what *is* the rainfall on any given watershed? Rain gages are set up at considerable distances apart, and by no means can measure the rainfall on any given contiguous number of square miles. But, apart from such considerations, why, when seeking run-off, should engineers turn their backs upon it, and go off poring over records of rainfall, and endeavor, by dint of much tribulation, to compute a relation between it and rainfall? That sort of thing was well enough in the 40's of the nineteenth century, when it was started, but to-day it is surely time that it be recognized as a false method of work, and engineers' energies should be concentrated on stream measurements and a comparison of such, when the future yield of drainage areas is in question.

It is submitted that by such comparisons or analogies much more reliable results in the line of yield prognostications can, to-day be obtained, when direct gagings are lacking, than rainfall studies, and computations based upon them, can ever furnish.

In short, it is time to put away childish things; and among such, in hydrological studies, it is clear, may be counted the numberless attempts that have been made in years past to compute from past rainfall observations the to-be-expected maximum, minimum or average annual, monthly, weekly or daily yields. To attempt to do so, even only to recite past or suggested methods of doing so, distracts from the pursuit of the much more promising lead furnished by the study of such run-off gagings as are already on record; and, in the opinion of the writer, is to be discouraged as a distraction, and as hindering an extension of run-off gagings and of results to be found from their study; as making for blindness or the obscuring of vision and for arresting progress.

RUN-OFF DIAGRAMS.

Having given a record of run-off gagings, how shall they be arranged for the use of the hydraulic engineer?

Now, confining ourselves to the considerations uppermost in the mind of the engineer of water *power* (not water supply), it has long been clear to the writer that there must be one best way; also that in the interests of efficient work and of an avoidance of wasted effort, this best way should be followed, rather than pursue the study of many such ways.

A mine of information on stream flows is contained in the reports of the U. S. Geological Survey on that subject, which have now attained nigh four hundred unbound volumes, some of them quite bulky, making a burden on the resources of engineers who pay the rent of their own offices and shelf-room. It is no exaggeration to say that for water-power purposes, giving all data needed for that purpose, these four hundred bulky reports could be condensed into four hundred single-page cuts contained in one such volume, and at an enormous saving to the work, time and expenses of the hydraulic engineer.

For the purpose of facilitating comparison and reducing all the records to the same specific scale as it were, the collected diagrams should be plotted to represent second-feet per square mile, instead of second-feet. Underlying details would not be lost, but if ever needed (a matter of some doubt) could be supplied by the Survey Office. In answer to an inquiry requesting suggestions, the writer had the honor to make the above recommendations to the Geological Survey office and here reiterates this his matured opinion on the subject.

If the daily discharges of a river at a certain point be plotted for the three hundred and sixty-five days of the year, *in the order of their magnitude* (not consecutively in the order of the date of their occurrence), a perfectly smooth curve showing the year's discharge will be produced. Take fifteen or twenty such years, if the records avail, and three such curves may be produced; one of average flow, another enveloping all the minima flows, and a third enveloping the maxima flows. And for a period of that length the discharge of that river, at that point, has been

portrayed practically for all time. Nothing, or little more, is needed in its hydrographic study, for the uses of a constructing engineer. Its original data may have interest for a meteorologist, when he philosophizes as to the relation between such three curves and rainfall data, but an engineer has nothing to do with that. The rainfall may be anything; it will not change the recorded run-off, nor the ranges of run-off shown by these three curves. And it is these data that are needed for useful purposes, — the province of the engineer, — in contradistinction to the pastures of recreation that invite the philosopher or scientist. The same data may also be presented, if preferred, in tabular form; would have to be, before they can be "boiled down" into the diagram which has been described. Such tables are presented in Trans. Am. Soc. C. E., 1907, p. 29, "Twenty Years' Run-off, at Holyoke, Massachusetts, of the Connecticut River"; and in H. R. Doc. 1400, 62d Congress, 3d Session, 1913, Fifteen Years' Run-off of the Potomac River, at Great Falls, near Washington, D. C.; while such diagrams are shown in *Engineering News*, September 4, 1913; H. R. Doc. 1400, above referred to, Plate 37; and Min. Proc. Inst. C. E., Session 1912-1913, Part 4, p. 95.

It has already been explained that in cases where such long records, or any such, do not exist, recourse must be had to reasoning from analogy; something that is not unknown when yield by means of rainfall computations is striven for. Having regard to location, upland or lowland, mountainous or flat land, size and shape of drainage area, area of pond or lake surfaces in it, and climate, it is the writer's firm belief that, by reasoning to-day from analogous cases of stream flow, better results will be attained than computations based on rainfall records can ever produce.

As an example of the tables and diagrams spoken of, one of each is here reproduced; the table, from the paper on twenty years' run-off of the Connecticut River; the diagram, from Doc. 1400 referred to.

The bold-face figures in the table, showing maximum and minimum in each horizontal line, give the data for the enveloping curves that have been spoken of. The two full lines extending

TABLE 3. — TWENTY YEARS' FLOW OF THE CONNECTICUT RIVER AT HOLYOKE, MASS.
Figures represent Second-Foot in Twenty-four Hours.

Day.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.	1898.	1899.
1	44 100	49 050	43 650	68 300	71 000	63 950	80 150	88 500	90 750	37 800	40 750	67 300	63 100	94 350	43 300	115 000	112 050	75 350	76 150	82 500
	28 900	35 100	30 850	30 550	49 500	44 350	42 700	63 550	65 150	12 300	30 650	34 450	42 950	42 550	33 400	50 800	61 950	53 650	50 750	67 250
	22 900	32 850	23 500	23 200	37 950	30 650	36 600	50 150	40 800	20 950	30 550	33 000	31 700	30 950	26 550	33 550	37 100	44 200	41 550	45 900
50	10 800	25 200	23 500	19 950	30 750	25 950	29 250	37 000	40 450	10 550	16 450	12 750	27 400	32 950	18 550	24 700	26 100	37 000	31 500	23 200
	17 550	20 100	22 150	15 200	27 700	25 950	25 450	27 600	31 700	24 800	30 050	28 800	23 500	28 200	16 050	21 950	23 150	32 950	25 850	17 700
	15 250	17 800	20 800	13 200	26 200	22 550	17 750	22 900	31 600	23 300	28 200	24 350	20 800	23 450	15 100	18 850	20 100	28 300	22 800	15 400
	14 250	10 600	18 900	13 500	24 250	19 200	17 600	18 650	26 350	20 500	24 600	20 250	17 150	17 000	13 950	10 200	18 300	20 350	21 000	14 000
	11 750	15 100	16 850	10 450	22 000	16 950	14 000	17 000	24 150	18 500	21 700	17 850	15 150	15 100	13 000	13 550	17 150	24 500	20 200	12 300
	10 900	14 300	15 300	9 000	18 950	16 300	14 050	17 000	24 150	18 500	21 700	17 850	15 150	15 100	13 000	10 900	15 950	22 950	17 850	11 450
	10 050	12 000	14 500	8 250	15 550	14 150	12 500	15 250	20 200	17 450	19 950	16 600	13 800	9 950	8 800	9 050	12 800	20 200	15 150	10 450
100	8 000	11 750	13 000	7 600	13 150	13 250	12 100	14 200	20 200	17 450	19 950	16 600	13 800	9 950	8 800	8 400	11 050	18 050	14 400	9 000
	8 500	11 000	12 500	7 000	12 300	12 400	11 500	13 950	19 250	16 650	18 450	14 500	13 250	9 100	8 200	7 750	10 700	16 800	13 750	8 150
	8 300	10 050	11 600	6 550	11 300	11 550	10 900	12 400	18 250	16 100	17 750	13 700	12 200	8 500	7 800	7 250	9 800	16 100	12 950	7 750
	7 950	9 100	10 500	6 950	10 300	11 050	10 250	11 550	17 600	15 550	17 100	12 500	12 200	7 800	7 400	6 300	9 300	15 300	12 450	7 200
	7 500	8 850	9 350	5 150	9 250	10 550	9 800	10 750	16 700	14 650	10 050	11 350	11 600	7 300	6 950	6 050	8 550	13 950	12 000	6 600
150	7 300	7 000	8 350	4 850	8 750	9 200	9 600	10 150	15 600	14 250	14 950	10 500	11 100	6 850	6 550	5 850	8 550	13 950	12 000	6 600
	6 900	7 150	7 500	4 650	8 150	8 850	9 200	9 850	14 300	13 350	14 400	9 600	10 250	6 450	6 250	5 200	7 700	12 650	10 700	5 650
	6 350	6 050	6 950	4 400	7 550	8 300	8 850	9 500	13 500	12 800	13 700	8 800	9 500	6 050	5 950	4 900	7 150	11 800	10 150	5 400
	5 350	6 350	6 400	4 100	7 200	8 950	8 500	9 150	12 400	12 150	13 400	7 600	9 100	5 900	5 700	4 750	6 850	10 550	9 700	5 350
200	4 600	5 500	5 750	3 900	6 700	7 800	8 100	8 850	11 400	11 050	12 800	7 200	8 600	5 050	5 450	4 550	6 500	10 200	9 200	5 250
	4 000	5 000	5 050	3 750	6 500	7 650	7 800	8 500	10 600	11 250	12 050	6 650	8 150	5 200	5 200	4 350	6 500	10 200	9 200	5 250
	3 500	4 750	4 850	3 650	5 700	7 250	7 400	8 250	9 200	10 850	11 400	6 000	7 850	4 900	5 050	4 350	6 250	9 700	8 750	5 150
	3 500	4 200	4 500	3 500	5 600	6 800	7 050	7 900	8 500	10 500	11 500	5 550	7 500	4 750	4 950	4 350	6 050	8 150	8 450	5 000
	3 350	3 800	4 150	3 300	5 350	6 000	6 000	7 050	8 000	9 850	10 900	5 550	7 000	4 400	4 800	3 950	5 800	8 550	8 550	4 950
250	3 200	3 700	3 800	3 400	5 100	5 250	6 000	7 350	7 350	9 500	9 600	5 250	6 000	4 450	4 750	3 800	5 250	8 000	7 700	4 500
	3 000	3 600	3 700	3 400	4 900	5 900	4 900	7 350	7 300	9 150	9 150	5 100	6 400	4 350	4 500	3 600	4 900	6 500	7 550	4 150
	2 850	3 400	3 500	3 350	4 600	5 550	4 900	7 150	7 100	8 650	7 950	4 850	6 150	4 250	4 500	3 500	4 950	5 250	7 200	3 950
	2 550	3 100	3 250	3 350	4 350	5 450	3 450	6 000	7 000	8 000	7 550	4 600	5 900	4 050	4 250	3 400	4 500	5 000	6 700	3 550
	2 350	3 000	3 300	3 100	4 150	5 250	3 300	6 300	6 800	7 550	6 850	4 400	5 550	3 900	4 000	3 300	4 400	4 900	6 150	3 300
300	2 150	2 950	3 450	2 950	4 100	5 000	3 200	6 150	6 500	7 250	6 500	4 150	5 150	3 850	3 600	3 150	4 300	4 700	5 850	3 200
	2 150	2 950	3 250	2 850	3 700	4 850	3 150	5 750	6 300	7 000	6 500	4 050	4 950	3 750	3 350	3 050	4 150	4 450	5 950	3 050
	2 050	2 950	3 150	2 850	3 600	4 600	3 000	5 400	5 800	6 600	6 000	3 600	4 700	3 600	3 300	3 050	3 900	4 350	4 750	2 800
	2 050	2 950	3 000	2 750	3 500	4 300	2 700	5 200	5 600	6 350	6 250	4 800	3 500	3 250	2 750	3 000	3 750	3 900	4 400	2 700
	2 000	2 950	2 900	2 500	3 100	4 150	2 600	4 300	4 800	5 500	5 900	3 150	4 400	3 200	2 450	2 950	3 450	3 700	4 000	2 500
350	1 750	2 850	2 850	2 300	2 950	3 850	2 500	4 150	4 700	5 450	6 450	3 050	4 300	3 050	2 350	2 900	2 850	3 550	3 600	2 400
365	1 650	2 700	2 400	1 950	2 650	3 050	2 100	3 650	3 450	3 650	3 550	2 900	4 150	2 800	1 900	2 850	2 700	3 350	3 450	2 350
															1 600	2 700	2 100	3 000	3 200	2 250

across the table mark the limits between which the economical capacity for turbines to be installed will ordinarily be found, concerning which more is to follow. The data for the curve of average flow (averages of each horizontal line) have not been computed, but can be readily found from the table.

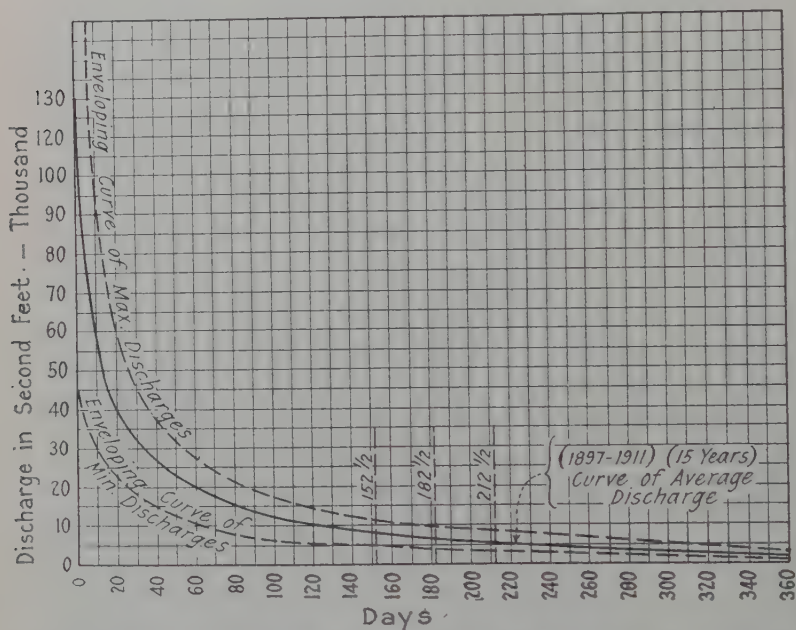


FIG. 2. CURVES PLOTTED FROM FIFTEEN YEARS' STREAM-FLOW RECORDS OF POTOMAC RIVER AT AQUEDUCT DAM, WASHINGTON, D. C.

The diagram will presumably need no explanation. It is the concise and true representation of the régime of the river, in this case the Potomac, near Washington, giving all data needed by a hydraulic power engineer. And, if we had such diagrams for the principal points on every river of importance in the United States, it would be the fulfillment of hydrographic study of river flow within the United States. A single volume containing such diagrams would then take the place of the several hundred volumes of undigested material relating to river flow

which now obstruct useful work and the exercise of judgment; not to mention the lucubrations of rainfall recorders and of their obsequious followers.

WARRANTED TURBINE CAPACITY TO BE INSTALLED.

In taking up this subject, let us assume that we speak here only of the ultimate development at any given mill-site. Power machinery may be installed at time intervals, as power is called for. Even the power house may be built in sections. Let us also recognize that while power dams and power houses are built to last forever and as a matter of fact naturally do endure on the average longer than most any other work an engineer is called upon to design and construct, yet the duration of such things as "load-factors" and given "peak loads" are in comparison but fading fancies. How, then, can they properly enter into a computation for power-house design in conjunction with factors that are eternal, or nearly so? The tendency of power-house management is constantly to strive for a load factor of one, and both the progress of invention and of sociology is working to that end. By the time a network of interconnected power wires, each arranged to convey a constant daily quantity of power, will have spread over all the thickly settled portions, or over the whole of the United States, farms included, which is rapidly being accomplished, where will the load factor and peak load be then? *

The state of electrical development just described is rapidly being accomplished in the Province of Ontario, Canada, as a state enterprise,[†] and there is nothing but notions of sociology to hinder its coming true in the United States by private enterprise.[‡] Another consideration which this thought brings up is the one of variable power from day to day at any mill site; very present to those who are operating or have operated water power on most any stream except on those constituting the outflow of the Great Lakes; and the subject of permanent and surplus

* *Electrical World*, March 11, 1916, p. 581.

† *Electrical World*, March 18, 1916.

‡ *Engineering Magazine*, February, 1916.

power; or, to use the later terms, of "primary" and "secondary" power.

Suppose we assume that there is no secondary power (there need not be); that it is all power that can be relied on to be at hand when called for. So far as the writer's judgment goes, based on ten years' experience in the administration of a water power, that is the only kind of power that should be offered for sale in the existing and the to-be-expected development of the business; in the interests of the seller, no less than in that of the buyer; and with the legitimate aid of heat engines and fall increasers to tide over low water and "back-water" troubles, and in spite of unavoidable annually recurring diminutions of power output, during nearly all the days of the year, there is no difficulty in attaining a uniformity of power output throughout every day of every year.

One might go further and prove that only by amalgamating heat engine and hydraulic power in this way can a full or complete return be gained from hydraulic power plant investments. All this was well understood full fifty years ago in New England manufacturing circles, if not elsewhere; but, with the advent of the electrical transmission of power, an army of ardent electricians, ill informed on hydraulic matters, were let loose upon an expectant country, and they had to learn all this over again. Some of them and their backers have not learnt it yet. We still hear of the minimum flow of the river on any one day in twenty years, as furnishing the measure of "primary" power, and there are great hydraulic power plants that needlessly waste over their dams, on more than half the days of an average year, a quantity of water which if properly utilized would generate 100 or 150 million kilowatt-hours annually, at a cost less than the fuel cost of the heat engines that must be installed to tide over *low-water* diminutions of normal power output.

Then there is the consideration of how much reservoir capacity or pondage is to be added to the power plant for the purpose of making the water supply more uniform, tending towards that happy era when there shall be no more times of low water and no more freshets.

A German writer has recently stated such a proposition as follows:

“ Procedure for the Determination of the Most Economical *Part* of the Annual Run-off to be used; Size of Reservoir; and Amount of Auxiliary Heat Power which should be selected in the Construction of Water-Power Plants.” *

As the learned author treats the subject, this includes a choice and determination: (a) Whether to use no water at all, or all the water that comes down the brook or river during the year; or what portion of the annual discharge of the stream is to be utilized; (b) whether to have no reservoirs, or reservoirs large enough to utilize the whole annual river flow; or what intermediary reservoir capacity is to be constructed; (c) whether to have water power only, or to use auxiliary heat engines; and, if any are to be used, to what extent; certainly a comprehensive program. And all this is to be answered strictly by computation, and results given by formulæ expressed in mathematical symbols! Does not this suggest the line: “ Out of too much learning become mad? ”

But let us analyze the task entered upon; (a) and (b) may be considered together, (a) being a function of (b). And economic reservoir capacity, to ordinary minds, is plainly a local consideration, to be answered in each case by the local situation, let the formulæ say what they will.

It is only very gradually that the mere idea of the applicability of the powers of eminent domain to the taking of land by condemnation for water-power purposes is being recognized in state constitutions and in court decisions, thence spreading to legislation (see a decision of the United States Supreme Court of January 24, 1916, in the case of the Alabama Interstate Power Co., opinion by Justice Holmes, as an important step forward in this direction); and without such right the opportunity of making use of computations relating to reservoir volumes would be somewhat doubtful. Then, again, are we to ignore topographical facilities or difficulties in such cases, in favor of the demands of general formulæ?

The writer believes that trial estimates will furnish a better

* Zeitschrift f. d. ges. Turbinenwesen, 1913, pp. 209, 230, 244.

guide in the vast majority of cases, very likely in all of them; and general experience has also indicated, at least as a beginning, to be modified if need be, by trial estimates in each case, how to answer division (c) of the problem as above stated.

This answer has already been indicated in the table of river flow above given, and may be stated as follows. The most economical discharge capacity of the turbines to be installed, so as fully to utilize the run-off at any mill site, is never very far either side on the diagram of the average river discharge on a day, than which there are as many days in the year of a greater as there are of a lesser river flow.

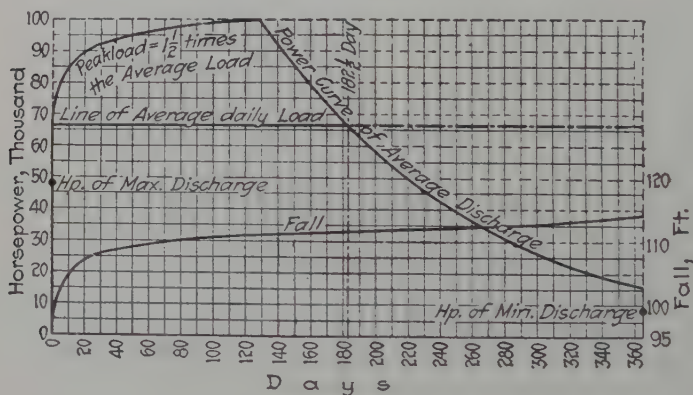


FIG. 3.

If, now, we have further the fall at the considered mill site appurtenant to the several river flows, fall also may be plotted as a curve; and from the two, quantity and fall, "Macaulay's schoolboy" could compute and plot the curve of resultant power for every day of an average year.

One factor more should, however, be taken into account: to accommodate peak loads or power variations occurring during the day, it is well to install wheels of a greater power capacity than has so far been indicated, running them normally at part gate. With all this entering into the computations, there will result the diagram given above, which presumably will need no explanation.

Auxiliary heat engine power, although its measure is indicated on the diagram, is not needed as a rule at first, except in process of developing the sale of power from the works, up to their full output capacity; and may thus be added gradually, as, indeed, may frequently, hydraulic turbine and even powerhouse capacity. All this makes for convenient elasticity in first installation, but will result, finally, in, what we have all along been aiming to attain, primarily or eventually, a full economical utilization of the natural resources of that power site.

MR. CHANDLER (*by letter*). — In Mr. Wood's interesting paper on "Power Estimates from Stream Flow and Rainfall Data," I notice the warnings offered against the indiscriminate application of the rule presented by Mr. C. E. Grunsky and quoted on page 91, for estimating run-off as a percentage of rainfall, and desire to emphasize that warning. During thirteen years' experience as hydrographer for the U. S. Geological Survey in charge of all the river-record work in North Dakota and some adjoining regions, I have found every one of the percentage run-off formulas as ordinarily stated to be misleading and useless for this northern prairie region, and to give computed results three, four, or even ten times greater than the actual facts here, even though the formulas may apply approximately well for the regions in which they are developed.

Mr. Grunsky first stated his rule that, if the annual rainfall is less than 50 ins., the percentage of run-off may be expected to equal approximately the annual inches of rain, many years ago, and it should be noted that, in the May, 1915, issue of the Proceedings, Am. Soc. C. E., although he quotes it as a general rule that "will give fairly close results for practically any portion of the United States," he also shows a curve applicable to the region with which he is himself most familiar (the Pacific slope), wherein the figures which the formula first stated would give are very much modified.

Similarly, now that the actual facts are available, very considerable modifications would need to be made in it to apply to the northern prairie region. In North Dakota, for example, with the long period average annual rainfall about 22 ins. at one side of the state and 14 ins. at the other, according to his

rule as first stated, the expected run-off would be from 4.8 to 2.0 ins. Actually, for different streams in different years it varies from 3.0 to 0.2 ins., and the long-period averages for most of the streams are between 0.6 and 0.9 ins.

If, however, the figures as stated in Mr. Grunsky's original rule are suitably revised upon the basis of the actual records now available for this region, I believe that the principle upon which it is based, if the constants are properly selected empirically, gives the most convenient short method for rapid approximate estimates; namely, that if the annual rainfall exceeds some fixed constant A , all the precipitation in excess of some other constant B (which is smaller than A) will appear in the run-off; if the rainfall is less than A , a variable percentage of it will appear in the run-off, such percentage being so related to the precipitation that the smaller the number of inches precipitation, the smaller the percentage.

MR. PIERCE * (*by letter*). — The subject of "Power Estimates from Stream Flow and Rainfall Data," covered by Mr. D. M. Wood in his paper, is so wide in its scope, and subject to so many variations for special conditions, that many more than the forty-two pages used by him would have been needed to cover all the details. As presented in his paper it is a treatise embodying a remarkably clear-cut exposition of methods actually used by hydraulic engineers who must make power estimates from the best data available, and who also must pass judgment on the reports of engineers, some of whom consistently make their reports unduly favorable while others may be inclined to reports that are generally unfavorable.

As preliminary to the design of water-power plants, especially those which are not likely to be supplemented by auxiliary steam power, emphasis should be placed on the need for accurate data regarding the actual daily flow of the stream. The records should, of course, be obtained as near the power site under consideration as is possible, although, as shown by Mr. Wood, data at other points in the same basin may be utilized by applying certain corrections. Outside of the same basin,

* District Engineer, United States Geological Survey, Water Resources Branch, Boston.

however, the conditions of physiography and topography may vary so widely as to introduce large uncertainties, even though the amount of precipitation may be practically the same.

Fig. 4, "Duration Curves for the Middle Branch of the Westfield River at Goss Heights, Mass., and the Quaboag River at West Brimfield, Mass. for the year ending Sept. 30, 1915

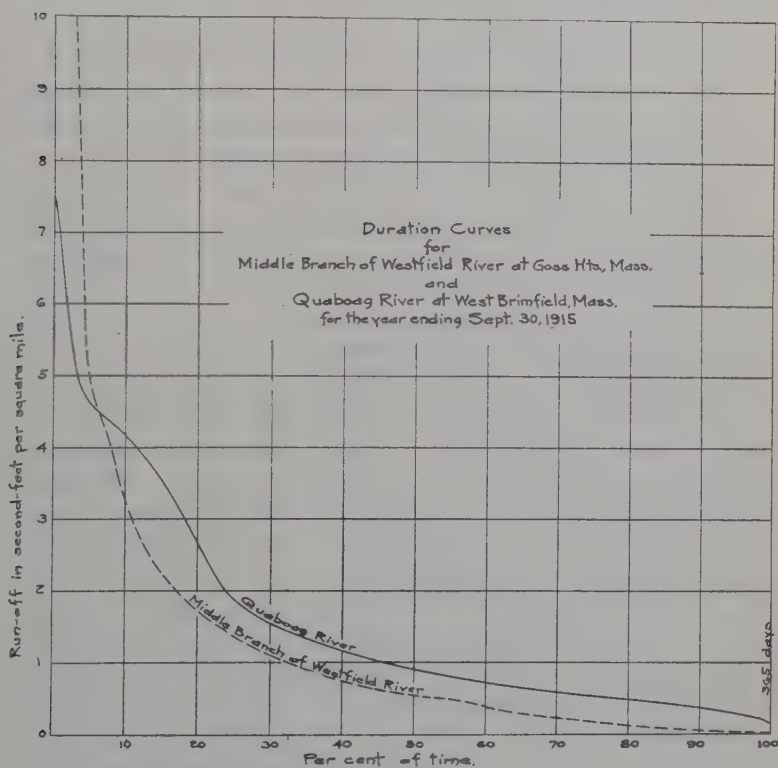


FIG. 4.

West Brimfield, Mass., for the Year ending September 30, 1915," shows the characteristic difference in flow of these two streams. The stations are only about thirty miles apart, the average annual rainfall probably differs not more than 5 per cent., and the average run-off for the year in second-feet per square mile is very nearly the same for the two streams, yet it may be seen

that the distribution of flow, as expressed in per cent. of time for which the same unit run-off is available, varies widely. It might be possible to supplement and extend short-term records at one place by means of comparisons with long-term records at a station not too far distant. Rainfall records alone would, however, never provide a safe means of estimating the distribution of run-off throughout the year. The writer is familiar with one locality having a rainfall of over 100 ins. a year, which is absorbed to such an extent that there are no perennial streams. This is an extreme case, but illustrative of the uncertainties that will occur in basing power estimates on rainfall alone.

When the base data concerning run-off have been obtained, the question naturally will arise as to the manner in which these shall be used, — whether in the form of duration or deficiency curves, mass curves, or by some other method. The duration or deficiency curve is probably the method most commonly used in a power study, and, although it may be plotted in various ways, it requires the use of daily discharge values. If the load factor is known or assumed, and sufficient pondage provided for, then the unit rate for a longer period may be used. In order that the base data may be available for whatever method is desired, the stream flow records as published in the Water-Supply Papers of the United States Geological Survey are arranged in tables giving the daily discharge in second-feet by days. Additional tables giving the average flow for each month, together with the maximum and minimum values for the month, and computed values of run-off in second-feet per square mile and depth in inches on drainage area, are published. For sections of the country where irrigation is practiced, the run-off in acre-feet is also given. With the base data arranged in this form, it is possible for the engineer to use whatever method he desires in making his power studies, and with publication the detail records become available for use by engineers in years to come without the delay and inconvenience of securing special copies when data are needed for analyses of stream flow.

About two years ago the Survey adopted the so-called "climatic" year, ending September 30, as the basis for annual computations, and the records as published in future Water-

Supply Papers will cover the period from October 1 to September 30. In order that records previously published on the calendar-year basis may be readily available for comparison with the present climatic-year system, the back records at the more important stations are being revised and republished on the climatic-year basis. Water-Supply Paper 415, containing a large amount of run-off data for rivers of Massachusetts, will soon be available, with the records arranged in this form. This division of the year will doubtless fit natural conditions more closely in some sections of the country than in others, but for the eastern part of the United States, and especially New England, it seems likely to give better results than the calendar year. On October 1 conditions are likely to be more nearly the same on consecutive years than can be expected on January 1, when the water equivalent in the form of snow and ice, which may be carried over from December to January, may range from 0 ins. to 8 ins. or more. Also, by having the computations for the ice period, which may extend from December to March, in one continuous group, much better results are obtained than when the year begins and ends with this uncertain condition. This latter feature would, of course, not be as pertinent to records kept at power plants as to river gaging stations, where the stage-discharge relation may be affected by the ice. There are other factors in favor of the climatic year, such as the preparation of the reports containing the data, which are perhaps better appreciated by the engineers who have to collect and assemble the material, than by those who use them for reference.

MR. GLINES* (*by letter*).—After reading through Mr. Wood's very valuable paper, the thought occurred that the objections to several of the methods mentioned, but discarded, might be overcome, and further refinement introduced into the accepted method, by the use of a different type of average.

Quetelet, a Belgian, in his study of astronomical and meteorological phenomena, was led to the discovery that the recurrence of all natural phenomena tended to fluctuate about a norm known as a *mode*, and that the tendency was for the number of occurrences to fall either side of this mode with mathematical

* With Stone & Webster Engineering Corporation, Boston.

regularity. He further found that, if the number of occurrences or instances were plotted as ordinates, the result would tend to approximate the binominal curve corresponding to that given by the mathematical law of probability or chance. Another way of defining the mode is as the position of greatest density or that factor which occurs the greatest number of times. Therefore, in any prediction of the recurrence of stream flow or rainfall, the principal factor we are interested in is that run-off or precipitation which has occurred the greatest number of times in the past. It is obvious that the arithmetical mean, in those cases where the fluctuations are great one side of the median, will not coincide with the mode. Just how much this may vary in an actual case it is proposed to show.

The twenty-year daily flow records for the Connecticut River at Holyoke for January were used in the following discussion. Table 4 shows the number of occurrences for the given rates of flow for the 20-year period between 1880 and 1899 and the 10-year period between 1890 and 1899. In the 20-year period, between 7 500 — 7 999 sec.-ft. occurred the greatest number of times, and the same is true for the 10-year period. We find that in the first period there are three distinct modes. In analyzing the mode between 2 500 — 2 999 sec.-ft. we find that while it occurred 43 times in the first 10-year period, Table 5 shows it occurred 26 times in 1880 and 17 times in 1882 and rarely if ever occurred in any other years. Undoubtedly this flow is abnormal. It might have been caused by ice, or, since it is recorded in the first three years of the record, may be an error. Therefore for the purpose of this discussion this mode may be neglected. Evidently the mode must lie somewhere between 6 000 and 7 999 sec.-ft. In order to locate the mode, smaller groupings were taken until it was finally found to be 7 750 sec.-ft. Now the arithmetical mean, which is the summation of the daily flows divided by the total number of days, is 9 827 sec.-ft. This shows a difference of over 21 per cent., which is certainly appreciable, and, when we consider it may throw our final analysis of a water supply or power study off by this amount, its importance is seen. The actual case taken is probably a very conservative one because it involves records

over a long period. The smaller the number of records at hand and the greater the magnitude of these records one side of the median, the greater will be this difference. On the other hand, the more records we have over longer periods, the more compensating this discrepancy becomes and the closer the arithmetical mean approaches the mode. In this particular instance it is obvious that the arithmetical mean is too greatly affected by the comparatively small number of occurrences at a high rate of flow. The mode, on the other hand, is not affected by these abnormal occurrences but is the common or most frequent occurrence. The accompanying curve (Fig. 5) illustrates how the

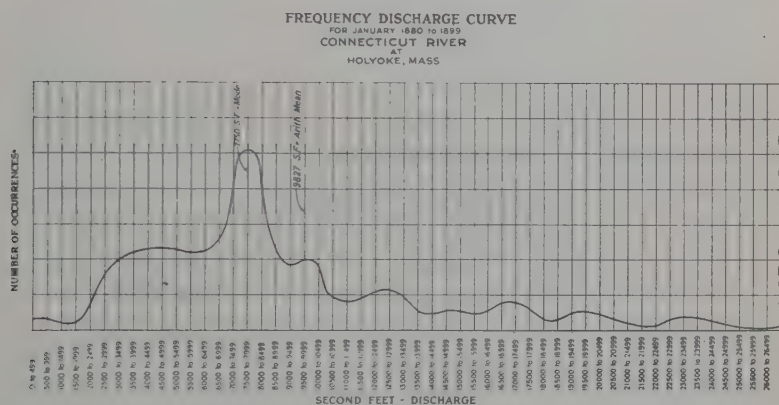


FIG. 5.

high flows of unfrequent occurrence affect the location of the arithmetical mean. It further illustrates how unfrequent the flows may be where the arithmetical mean lies. Many practical applications of this curve may be suggested, such as the study of relay and secondary power possibilities. It is believed that the mode would be a much better type of average to use in comparisons of adjacent drainage areas.

The question as to how far back records should extend, and what percentage of error may creep in by using short-term records, is one which while pertinent to the subject would form a discussion in itself.

It should be pointed out that there might be a case where there is not a well-defined mode, in which case the type of average used becomes a matter of judgment.

A more complete discussion of this type of average may be found in any book on statistics. Bowley's "Elements of Statistics" has a very good discussion. Dr. M. T. Copeland, of the Harvard Business School, proposes to publish this fall a book on "Statistical Methods" which will contain many practical applications of this method to ordinary business problems, so that the average business man is destined to hear a great deal about this type of average in the very near future. Statisticians, economists and sociologists have used this type since its discovery by Quetelet. Exponents of scientific management are using it in fixing standards of operation from and at which bonuses, etc., are figured.

TABLE 4.

10- AND 20-YEAR RUN-OFF RECORDS — CONNECTICUT RIVER AT HOLYOKE
ARRANGED IN 500 SEC.-FT. INTERVALS.
NUMBER OF OCCURRENCES.

	20-Yr.	10-Yr.		20-Yr.	10-Yr.
0 — 499	3	0	10 500 — 10 999	8	3
500 — 999	6	1	11 000 — 11 499	8	5
1 000 — 1 499	2	1	11 500 — 11 999	11	7
1 500 — 1 999	1	1	12 000 — 12 499	10	6
2 000 — 2 499	6	3	12 500 — 12 999	13	7
2 500 — 2 999	47	4	13 000 — 13 499	4	3
3 000 — 3 499	25	19	13 500 — 13 999	9	2
3 500 — 3 999	13	12	14 000 — 14 499	2	1
4 000 — 4 499	16	14	14 500 — 14 999	9	7
4 500 — 4 999	23	18	15 000 — 15 499	5	3
5 000 — 5 499	23	14	15 500 — 15 999	3	0
5 500 — 5 999	21	11	16 000 — 16 499	6	
6 000 — 6 499	24	21	16 500 — 16 999	4	
6 500 — 6 999	22	11	17 000 — 17 499	9	
7 000 — 7 499	49	16	17 500 — 17 999	6	
7 500 — 7 999	50	24	18 000 — 18 499	3	
8 000 — 8 499	30	13	18 500 — 18 999	1	
8 500 — 8 999	23	8	19 000 — 19 499	6	
9 000 — 9 499	18	10	19 500 — 19 999	5	
9 500 — 9 999	22	9	20 000 — 20 499	4	
10 000 — 10 499	22	10	20 500 — 20 999	3	

7 750 = Mode. 9 827 = Arith. mean. 21 ± % = Difference.
Forty-six instances over 21 000 sec.-ft. in 20-year period.

TABLE 5.
ANALYSIS OF FLOWS BETWEEN 2 500-2999 SEC.-FT.

1880	26	1887	0	1894	0
1881	0	1888	0	1895	2
1882	17	1889	0	1896	0
1883	0	1890	0	1897	0
1884	0	1891	0	1898	0
1885	0	1892	0	1899	0
1886	0	1893	2		

MR. BARROWS* (*by letter*).—The writer has read with interest the paper of Mr. Dana M. Wood on "Power Estimates from Stream Flow and Rainfall Data," published in the March, 1916, JOURNAL, in which outlines of numerous methods in use for solving problems relating to estimates of power are comprehensively presented.

The writer regrets that, owing to pressure of other matters, he is not able to add materially to the discussion of this paper, but will comment briefly on certain features.

Use of Precipitation Data.

Where data of run-off covering a considerable period of years are available at or near the power site, power estimates can be made with considerable certainty. The opposite extreme occurs in the case where little or no run-off data are available and where resort must be had to the use of precipitation data. The writer has found in numerous studies of this kind that monthly ratios of run-off to precipitation are of little value, as in a given month these ratios will vary very widely, even for the same total precipitation during the month, depending on the distribution of the precipitation during the month and the conditions for some time prior to the month in question. By dividing the "water year" into perhaps three periods, better results can be obtained in cases where storage is contemplated and the natural flow over short periods of time is not essential. A more satisfactory method of treatment in such a case, however, often

* Consulting Engineer, Boston.

consists in estimating the water losses and subtracting these from the precipitation to get the probable run-off. The water losses from land area may be considered substantially as (1) soil evaporation; (2) interception losses (that is, rainfall caught by vegetation and evaporating before reaching the ground); and (3) transpiration losses, or practically the requirements of growing vegetation.

As regards soil evaporation, a considerable amount of data is available from various lysimeter measurements. Interception losses have been determined only to a very slight extent, although some data are available on this subject from experiments made abroad. Transpiration losses have been determined fairly well for different kinds of growing crops by Messrs. Briggs and Shantz.*

To make an intelligent estimate of run-off based upon precipitation, taking into account the above factors, requires of course a knowledge of the drainage area and of the characteristics which affect the above factors.

Obviously it is difficult or impossible to measure separately these different losses on a given drainage area, but their determination by experiment upon small areas and the checking up of estimated losses with actual run-off measurements affords an interesting field for research in which there is opportunity for much effort.

The writer questions the desirability of any general assumption that precipitation varies directly with elevation. While there is usually an increase in precipitation with elevation, at least in the general vicinity of the Atlantic and Pacific coasts, a much safer method of procedure consists in plotting a curve in which the arguments are elevation and, say, mean annual precipitation, to ascertain what precipitation is likely for a given elevation, selecting data from stations adjacent to the locality in question.

Storage Studies.

Studies of the effect of storage capacity on stream flow can be divided into two general classes: (1) Where the storage reser-

* See Bulletin 281, U. S. Dept. of Agriculture, Bureau of Plant Industry.

voir is at some distance from the power plant. (2) Where it is closely adjacent to or at the power plant.

In the first case, where the reservoir is at some distance from the power plant, the use of the mass curve is not practicable, but studies are best made by means of a hydrograph plotted on the basis of the yield of the uncontrolled portion of the drainage area, between the reservoir and the power plant, accompanying the hydrograph by tabular computations and a reservoir depletion curve, as noted by Mr. Wood.

In the case where the reservoir is at or near the power plant, the mass curve method is useful and probably better adapted. The results of a mass curve study can be very effectively presented in what may be called "resultant curves," which show the relation between any given amount of storage capacity and the resulting dependable flow of the stream.

In operating storage there are two extremes in method, — (1) that in which the attempt is made to obtain a maximum of primary power, which will require storing water over more than one season; (2) the other method, and that more commonly used, consists in practically emptying the storage reservoir each season. This will commonly mean a greater output in total kilowatt-hours annually, but a lesser amount of primary power. As a rule, however, this second method is more attractive financially, especially where the plant is tied in with a system where auxiliary steam is available in the low-water season.

Refinement of Computations.

The futility of a degree of precision, in computations relating to power estimates from stream flow, greater than that obtainable with the slide rule, is evident, and the writer believes that more care in this respect should be taken generally by engineers, — especially in presenting the final results of investigations and estimates, — not to retain superfluous significant figures which, although perhaps impressive in some cases to the layman, really mean nothing.

As Mr. Wood states, it must be kept in mind that power estimates are based upon past records, and are simply guides to assist the judgment in conservative estimates of the probable

future output of a power plant. They involve the basic uncertainty of all estimates relating to factors dependent in the broad sense upon meteorological conditions which cannot be accurately predicted in advance.

MR. WOOD * (*by letter*). — In his discussion Mr. Hazen has suggested a method of analyzing stream-flow data which apparently allows of a ready comparison between records in different basins, by using the rates of flow as percentages of the mean flow. While the writer has not had time to make any extensive comparisons of records by this method, those he has made leads him to believe that the suggestion will prove a very useful one.

In applying the results of such comparisons to a basin where few or no run-off records are available, it appears to be necessary to arrive at a fairly reliable estimate of the mean flow as a starting point, afterwards assuming its distribution throughout any given period of time similar to some one of the known cases.

After giving considerable thought to this method, the writer is of the opinion that, for purposes of making power estimates, the results might perhaps be presented in slightly different form from that suggested by Mr. Hazen. The flow corresponding to any given "per cent. of time available" can first be picked off from the duration curve of flows and then its percentage relation to the mean flow computed, rather than vice versa. This would facilitate putting the flow records into the useful form indicated in the original paper.

As an example of this slight amendment to Mr. Hazen's valuable suggestion, Table 6 is presented giving the results of an analysis by four of the methods cited in the original paper, of a 38-year run-off record of the Mississippi River at Nashville, Ia., the total drainage area being 119 000 square miles.

In addition to the interesting variations in percentages of mean flow available for various percentages of time for such a large drainage area and long-term record, this table also shows clearly the differences resulting from the use of four different methods of analyzing the basic data. It indicates the greater reliability of the daily flow analysis.

* Author's closure.

TABLE 6.

PERCENTAGE OF MEAN FLOW AVAILABLE FOR GIVEN PER CENTS. OF TIME
FOR DIFFERENT METHODS OF ANALYZING BASIC DATA.

Per Cent. of Time Flow was Available.	Averaged Calen- dar Mos. for Period of Record (38 Yrs.).	Averaged by Mos. when arranged in order of Dry- ness but by Calendar Years.	Mos. arranged in order of Dryness regard- less of Calendar Years.	Days arranged in order of Dryness (Daily Duration Curve Method).
100	19.5	19.5	19.5	15.6
95	44	34	30	28
90	48	38	35	32
85	50	43	38	36
80	51	49	42	40
75	58	56	47	44
70	72	63	54	49
65	78	66	58	54
60	80	71	64	61
55	81	76	71	67
50	84	81	79	75
45	88	86	89	83
40	102	96	100	94
35	116	109	110	105
30	124	124	123	118
25	142	140	135	135
20	163	155	151	155
15	166	171	167	178
10	171	186	195	205
5	174	212	245	249
0	408	408	408	491

Mr. Herschel calls attention to the dangers of relying upon rainfall data for the determination of run-off. In the original paper it was stated that such methods should be used only as a last resort, but an attempt was made to call attention to the value of rainfall statistics in determining the characteristics of the period of years covered by any particular run-off records.

For example, how could one feel assured that the twenty years' run-off record at Holyoke is typical of a much longer period of years, unless it is studied in connection with rainfall data? Unfortunately there are so few records covering a longer period of years than those at Holyoke that, even with the help of Mr. Hazen's suggested method of comparing run-off records, much uncertainty would still exist regarding the probability of recurrence unless the two sets of data are considered together.

The several methods of using rainfall and run-off data were

introduced in the original paper for the purpose of showing briefly the differences in results likely to be obtained by their use. In the many engineering reports which the writer is constantly reviewing, he has seen used all of the methods of analyzing run-off data cited; and that engineers continue to use methods of doubtful value would seem to be reason enough for calling attention to the possible variations in results, and to suggest a method which the writer has worked out and had the opportunity to compare with actual operating conditions.

Briefly, the daily duration curve method has been employed whenever possible, but, in lieu of that, the method of arranging the run-off by months in order of dryness regardless of the occurrence by calendar years has been found to give the most reliable results, especially if a reduction of a few per cent. is arbitrarily made for correction to a daily basis.

The writer would not like to see the United States Geological Survey suppress the publication of the basic flow data, because many important questions arise which can only be answered by their study. It is understood that, in the future, duration flow tables are to be added to the other published data, which is to be commended. Considerable redundancy might be avoided in the publications if a system of loose-leaf bulletins was adopted, similar to that used by many of the large manufacturers in publishing their catalogues, thus facilitating filing the records of one basin together.

Mr. Herschel, in his discussion on power estimates, has taken the special case of the point of view of the manufacturing concern with fairly steady load conditions, while the writer endeavored, by means of his power curves, to present a general case applicable to all kinds of variable flow and power conditions, with or without pondage available, and with or without relay requirements at times of low or high water, or both.

It is difficult to see why the economical plant capacity is more dependent upon flow conditions than upon financial considerations, the latter involving as they do a study of the market conditions, including the expected load factors.

In central-station practice, the annual load factors realized are usually in the vicinity of 30 per cent. to 50 per cent. rather

than 100 per cent. Even in the case of manufacturing industries with reasonably steady load conditions, more than an 80 per cent. load factor is rarely obtained. With many plants tied in together, the load factors will decrease rather than increase, except for short periods of time on the individual plants. Never can a load factor of unity be obtained until the ideal condition is reached when every power user utilizes his full peak demand for twenty-four hours a day, for every day in the month and year.

The minimum daily flow is of importance even in the case of a relayed plant. With given relay capacity, it indicates the total amount of power which can be guaranteed, with given load factor and pondage conditions.

A majority of both industrial and central-station plants can utilize to good advantage a certain amount of "secondary" water power. How much of this secondary power should be relayed is entirely a question of economics, — of dollars and cents. No two cases are exactly alike, so that each must be studied by itself. A general method of making such studies was given in the original paper.

A general "utilization" factor was discussed, which included among other things an allowance for "power factor" and also for "regulation." Each of these problems can be studied by themselves if so desired, the method of developing power curves as suggested allowing of ready corrections for such further detailed analysis.

An interesting problem which the local manager is always facing is that of the use or sale of surplus power at varying load factors, perhaps bringing up such questions as the advisability of further machinery installations. The power curves afford a means of making such studies, but the general theory as presented in the original paper was not complicated by introducing such questions.

In Mr. Pierce's excellent discussion, attention is called to the errors that may arise from applying records in one basin to another. It is unfortunate that we do not always have actual records in the basin under consideration, nor can we sometimes wait the necessary time to obtain them. It then becomes neces-

sary to do the next best thing and make as close approximations as possible from other sources of information.

Mr. Glines' suggestion of the use of the "mode" was received too late to allow the writer to make trial of it in any actual cases. It undoubtedly suggests another convenient tool for making a reasonably correct analysis of run-off data.

In closing, the writer wishes to call attention to the fact that on page 80 he inadvertently omitted mention of the run-off records compiled by the United States Engineer Corps as a useful source for basic data.

MEMOIR OF DECEASED MEMBER.

ERASMUS DARWIN LEAVITT.*

ERASMUS DARWIN LEAVITT, honorary member of the Boston Society of Civil Engineers, died in Cambridge, Mass., on March 11, 1916, where he had lived for many years. He was born in Lowell, Mass., on October 27, 1836, and was the son of Erasmus Darwin and Almira (Fay) Leavitt.

Mr. Leavitt's education was in the public schools of Lowell, and in 1852 he entered the Lowell Machine Shop as an apprentice, where he served three years, after which he was employed by Corliss & Nightingale one year. In 1858 he was employed by Harrison Loring at the City Point Works at South Boston, as assistant foreman, and had charge of the construction of the engine of the U.S.S. (flagship) *Hartford*. From 1859 to 1861 he was chief draftsman for Thurston, Gardner & Co., Providence, R. I.

He served in the Navy during the Civil War, in sea service and construction work, and for two years was instructor in steam engineering at the Naval Academy at Annapolis, resigning in 1867.

In 1867 he entered the practice of mechanical engineering, making a specialty of pumping and mining machinery.

His fame may be said to have begun with the installation of the pumping engine at Lynn, Mass. This was followed by the engine for Lawrence, Mass. Both of these engines were tested by some of the best-known engineers in the country, and the high results obtained were of great interest to the profession.

In 1874, Mr. Leavitt was appointed consulting and mechanical engineer of the Calumet & Hecla Mining Company, and held that position until 1904. During this time he designed and supervised the construction of the large equipment for this com-

* Memoir prepared by Charles T. Main and Will J. Sando.

pany. During this period he acted as consulting engineer for many other companies and municipalities.

He was one of the organizers of the American Society of Mechanical Engineers. The Society History says:

"Mr. Leavitt was best known for his notable successes in the design of high-duty compound pumping engines for city water-works service. . . . He served as president of the Society during 1883-84. . . . He positively declined a second term as president on the principle . . . that the honor of the office should be widely conferred."

He was on intimate terms with the most prominent engineers of his active days. He was of a modest and retiring nature, and his acquaintance with members of the Society was not extensive.

Mr. Leavitt as a designer probably did more than any other engineer in establishing sound principles of design and the use of the best of materials in construction, realizing that, while economy in running was to be striven for, reliability of service was more important.

Mr. Leavitt received the degree of doctor of engineering from the Stevens Institute of Technology in 1884. He joined the Boston Society of Civil Engineers, January 21, 1880, and was made an honorary member in 1908.

He was a member also of the following societies: American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers (honorary, 1915), American Society of Naval Engineers (honorary), Institution of Civil Engineers, British Association for the Advancement of Science (life member), Franklin Institute, fellow of the American Academy of Arts and Sciences, New England Water Works Association (honorary, 1906).

Mr. Leavitt married Annie Elizabeth Pettit, of Philadelphia, on June 5, 1867, and he is survived by three daughters, two of whom are married.



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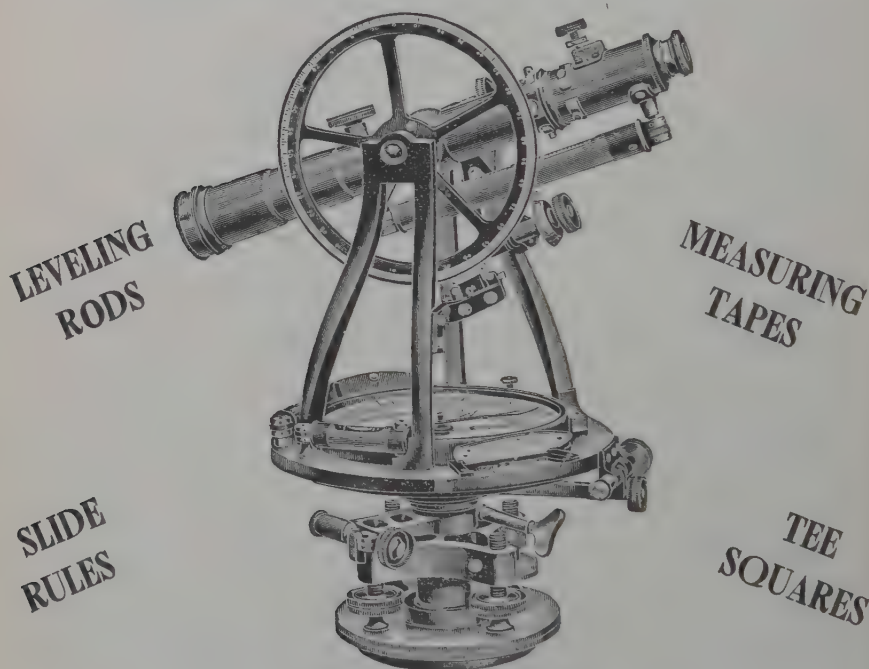
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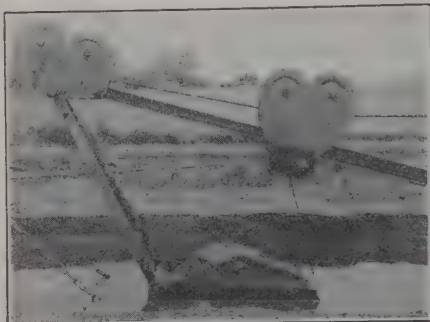
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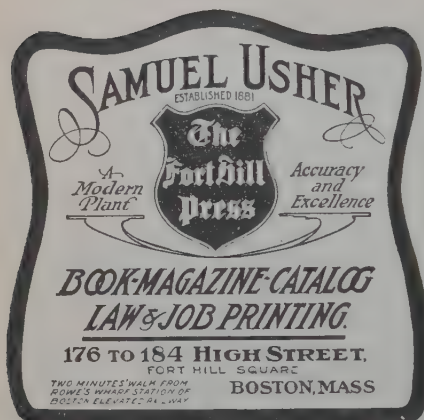
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